WINTER-22 EXAMINATION

Model Answer

Subject title: Plant Utilities | Subject code 22311

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

8)As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q No.		Answer	Marking scheme
1		**Attempt any five**	**10**
1	a	**Permanent hardness**: It is the hardness developed in water due to presence of chlorides and sulphates of calcium, magnesium or other heavy metals. It is destroyed by chemical process.	2
1	b	**Enthalpy of evaporation** It is the amount of heat required to convert one kilogram of water at a given temperature and pressure into steam at the same temperature and pressure.	2
1	c	**Uses of air in industry:** i) To clean work shop ,generators and machine. ii) For cooling of furnace. iii) Compressed air used in oxidation of acetaldehyde to acetic acid in liquid phase reactor. iv) Oxidation of nitrogen oxide to nitrogen dioxide in nitric acid plant. v) To exhaust the fumes of HCl gas, by exhaust blower. **vi)** fan air used in solid fuel boiler.	½ mark each for any 4
1	d	**Different types of refrigerant:** 1. Ammonia 2. carbon dioxide 3.sulphur dioxide 4. isobutene 4. Methyl chloride 5. methylene chloride	½ mark each for any 4

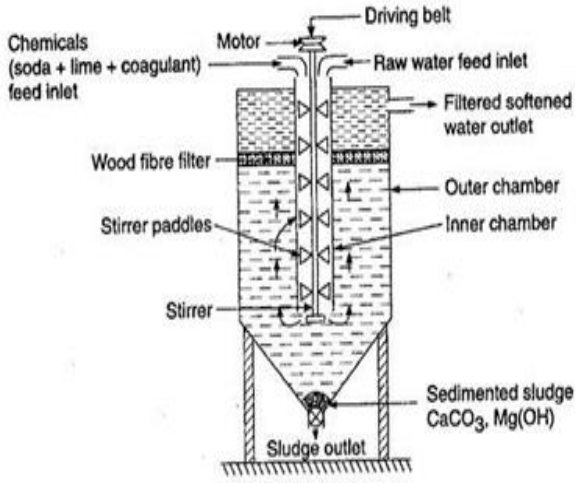
		6. Freon-22 7. Freon-11 8. Freon 12	
1	e	**Coefficient of Performance**:(COP) Working performance of any machine is usually expressed by output/input ratio known as efficiency. In refrigeration it is denoted by C.O.P. (β). COP= refrigeration effect/ work input to produced R.E. β =RE/W	2
1	f	**Degree of saturation:** It is the ratio of Mass of water vapour associated with unit mass of dry air to Mass of water vapour associated with unit mass of dry saturated air **Relative humidity:** It is the ratio of mass of water vapour in air of given volume at a given temperature to the mass of water vapour in same volume at same temperature when air is saturated	1 1
1	g	**i)Dry bulb temperature:** Temperature recorded by ordinary thermometer is called dry bulb temperature. **(ii)Wet bulb temperature:** It is the temperature indicated by thermometer whose bulb is covered with cotton or muslin wire wetted with moisture	1 1
2		**Attempt any three**	**12**
2	a	**Reactions in Zeolite process for softening of water are :** $CaCl_2$ (or Ca SO_4) + Na_2Ze → CaZe + 2NaCl (or Na_2SO_4) $MgSO_4$ (or $MgCl_2$) + Na_2Ze → MgZe + Na_2SO_4 (or 2NaCl)	4

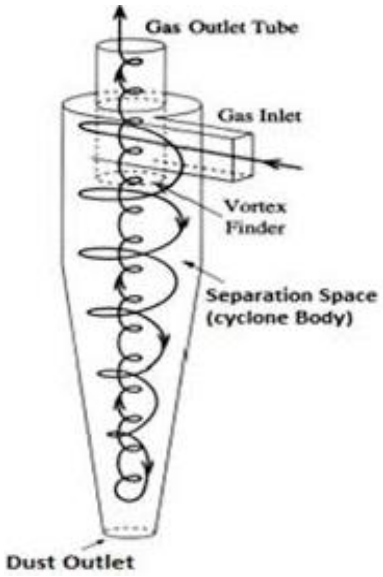
		$Ca(HCO_3)_2$ (or $Mg(HCO_3)_2$) + $Na_2Ze \rightarrow CaZe$ (or MgZe) +2 $NaHCO_3$	
2	b	**Comparison of fire tube and water tube boiler: (any 4)**	1 mark each

	Fire tube boiler	**Water tube boiler**	
1) Furnace position	Inside boiler shell	Outside shell	
2)Drum size	Large	Small	
3)Heating area utilization	Not effective	effective	
4)Use of fuel	Not used very efficiently	Effectively utilized by multipass flow	
5) Overheating or tube failure	Furnace surrounded by water, so danger of overheating is less as long as water level is maintained.	Furnace not surrounded by water, so if circulation of water inside tube is not proper, tube failure can occur.	
6)High pressure	Making large drum for high capacity and high pressure is very difficult	Drum size small, so drum can be made very strong for very high pressure.	
7) Production of steam	Generates low pressure steam	Generates high pressure steam	
8) Space	More space	Less space	
9) Operating cost	Low	High	
10) Scale formation	Low	Chances are high	

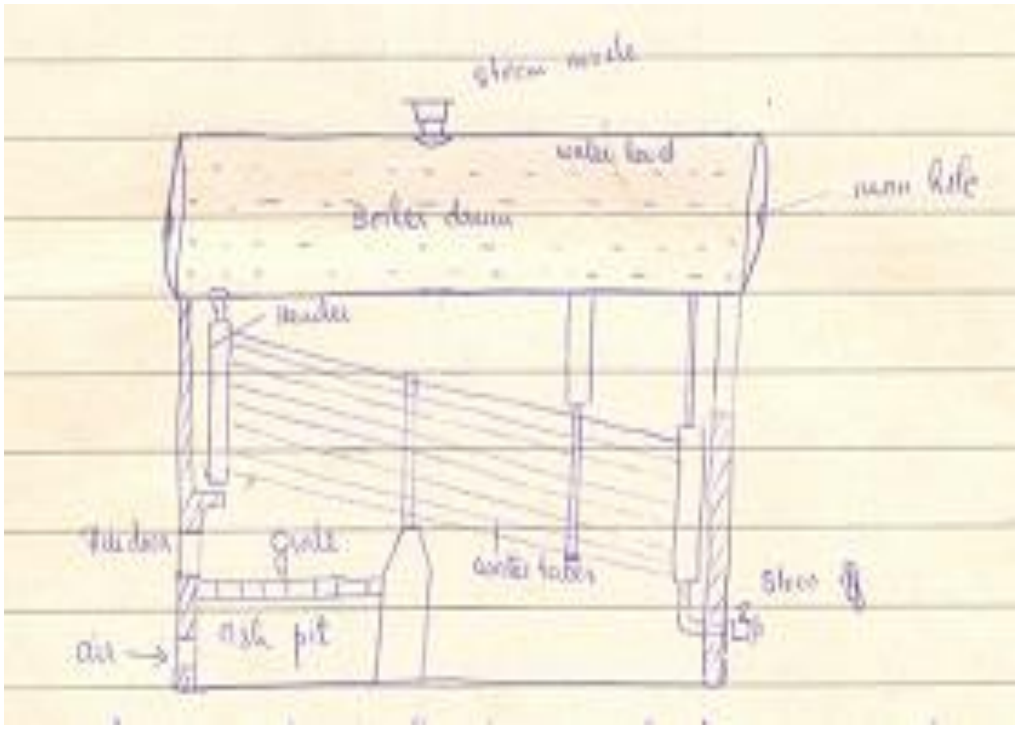
<table>
<tr><td>2</td><td>c</td><td>Compare between temporary hardness and permanent hardness:
<table>
<tr><th>Temporary hardness</th><th>Permanent hardness</th></tr>
<tr><td>This type of hardness is due to soluble bicarbonates of calcium and magnesium</td><td>This type of hardness is due to soluble chlorides and sulphates of calcium and magnesium</td></tr>
<tr><td>Known as carbonate hardness</td><td>Known as non carbonate hardness</td></tr>
<tr><td>This hardness can be removed by simple process such as boiling.</td><td>This hardness cannot be removed by simple process. Lime soda, Zeolite, Ion exchange treatments are needed</td></tr>
<tr><td>Methods used to remove temporary hardness cannot be used to remove permanent hardness.</td><td>Methods used to remove permanent hardness also remove temporary hardness from water.</td></tr>
</table></td><td>1 mark each</td></tr>
<tr><td>2</td><td>d</td><td>Construction and working of Induced Draft Cooling Tower:
Construction:
Cooling towers are employed to cool utility cooling water by direct contact with air. The parts of a cooling tower are
1.Water spray nozzle: water is sprayed in the cooling tower at the top with the help of nozzles. The spray helps to atomize the water in small droplets which results in increase in surface area of water and hence faster cooling.
2.Mist eliminator: They are placed just above the spray nozzle to reduce the loss of water and thus protect the fan blades from corrosion in the case of induced draft tower.
3.Cold water basin: It is the basin below the cooling tower where the cooled water accumulates and from where it is send to various heat exchange units.
4.Fill or packing: They are provided in the cooling tower to increase the</td><td>3</td></tr>
</table>

		surface area for heat transfer and evaporation. They create obstacles in the path of water and air flow due to which thorough mixing of air and water takes place which results in attaining adiabatic equilibrium. 5.Fan: Fan is mounted at the top portion of the cooling tower. **Working:** Hot water is sprayed into the cooling tower through the spray nozzle. As it passes through the fills through mixing of water and air takes place and heat is removed from the water. The fan mounted at the top pulls the hot air through the fills and cooled water gets collected in the cold water basin.	1
3		**Attempt any three**	**12**
3	a	**Uses of industrial water: (Any 4)** Use as a plant cleaning Use as a make -up water for power generation system Use in fine paper production Use in food, paper, chemicals , refined petroleum Use as feed for boiler For bleaching process in paper and pulp industry Use in sugar industry Use pharmaceutical industry Use for cooling and chilling operation in industry	1 mark each
3	b	**Lime soda process:** Types are:Batch lime soda process & Continuous Lime soda process Hot Lime soda Process	

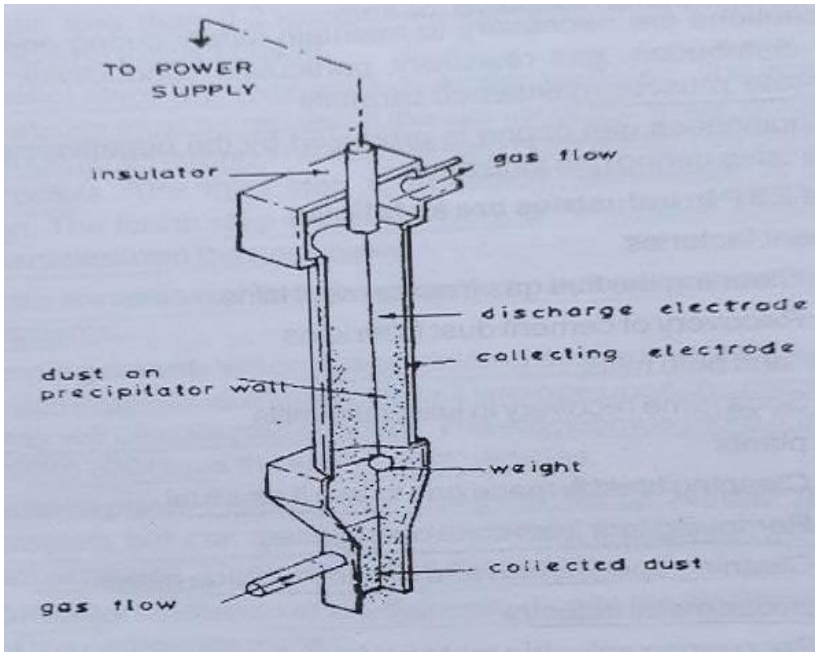
		 Chemical precipitation is one of the more common methods used to soften water. Chemicals normally used are lime (calcium hydroxide, Ca(OH)2) and soda ash (sodium carbonate, Na2CO3). Lime is used to remove chemicals that cause carbonate hardness. Soda ash is used to remove chemicals that cause non-carbonate hardness The lime-soda method of water softening must be followed by sedimentation and filtration in order to remove the precipitates. Ion exchange is accomplished by passing the water through columns of a natural or synthetic resin that trades sodium ions for calcium and magnesium ions.	2 2
3	c	**Duties of boiler inspector:** Confirm all boilers are registered. Make sure that all boilers are working according to act. Check and examine the boilers. Advise the employer regarding boilers maintenance , cleaning etc. Maintain the record of registered boilers.	4

		The pressure should be noted. Inspect boiler for leaks. Inspect safety devices on a daily basis, running tests and reporting any unusual situations. Monitor boiler water and fuel levels, making adjustments and activating valves as necessary to keep the boiler operational. Maintain records of operation, fuel and water levels, completed maintenance and other data. Steam boiler inspectors work to make sure boilers stay in good condition, helping identify potential flaws before they become worse.	
3	d	**Cyclone separator:**  **Working**: Cyclone separators work much like a centrifuge , but with a continuous feed of dirty air. In a cyclone separator, dirty flue gas is fed into a chamber. The inside of the chamber creates a spiral vortex. This spiral formation and the separation is shown in Figure . The lighter components of	2 2

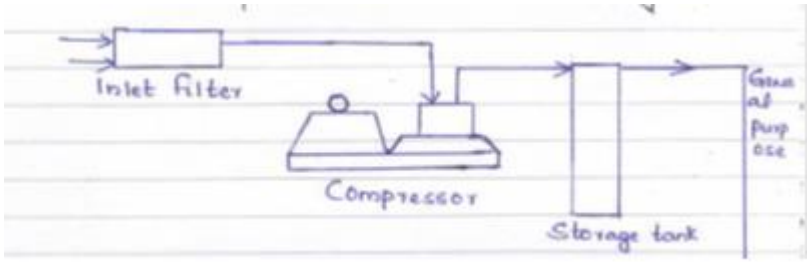
		this gas have less inertia, so it is easier for them to be influenced by the vortex and travel up it. Contrarily, larger components of particulate matter have more inertia and are not as easily influenced by the vortex. Since these larger particles have difficulty following the high-speed spiral motion of the gas and the vortex, the particles hit the inside walls of the container and drop down into a collection hopper. These chambers are shaped like an upside-down cone to promote the collection of these particles at the bottom of the container. The cleaned flue gas escapes out the top of the chamber.	
4		**Attempt any three**	**12**
4	a	**Scale formation in boiler:** Feed water contaminants such as calcium, magnesium, iron, silica, and aluminum are the major causes of deposit formation. Scale formation occurs due to salts that are not completely insoluble in the boiler water. Hence the salts reach the surface in a soluble form and precipitateBoiler scale is caused by impurities being precipitated out of the water directly on heat transfer surfaces or by suspended matter in water settling out on the metal and becoming hard and adherent. in a boiler causes impurities to concentrate. This interferes with heat transfers and may cause hot spots. **Removal of scale:** With the help of scrapper, knife , blades or piece of wood or by wire brushing, if the scale is loosely adhering. By giving thermal shocks. By heating the boiler and then suddenly cooling with cold water. By dissolving them in some chemicals.	2 2

		By frequent blow-down operation.	
4	b	**Babcock and Wilcox Boiler** Diagram  Babcock and Wilcox boiler has one horizontal drum mounted on the top of the structure and series of inclined water tube below the drum. The angle of inclination of water tube is about 15°. In front each tube a hand hole is provided for cleaning and inspection of tubes. The water tubes are connected to each end of drum through uptake header and down take header. The furnace is placed just below the uptake header. Baffle plates are provided between tubes to deflect and direct hot gases so that flue gases make passes over tubes for three times before it goes to chimney through smoke chamber. The dampers provided at the inlet of chimney to regulate the draught. The anti-	2 2

		priming valve provided at the inlet of superheat tube filters the water content in the steam. The entire boiler except furnace is hung by metallic sling or wrought iron girders, which enables free expansion and contraction of drum and water tubes during the thermal cycle. Mud collector is at the lowest point of the boiler, it helps remove mud particles. Brickwork encloses all the unit. The lower half of boiler drum is filled with water by feed valve. This water enters the water tubes through the down take header. Fuel burns inside the furnace and flue gases rise upward toward the water tube. Baffle plate makes sure the flue gases pass over the water tubes three times. As flue gas passes over the water tubes it exchanges heat with water through the tube walls. The heated water then flows to uptake header side. The hot water and steam then rises and enters to boiler drum. The circulation of water inside the tube is maintained by the natural convection. The steam is then escaping from water and collected at the top half of the drum, and water is collected at the bottom half of the drum. The water then again flows to the water tube thereby completes its cycle of circulation. The collected steam then flow to the superheat tube through anti-priming pipe. The function of anti-priming pipe is to filter the water content in the steam and allow the dry steam to enter to superheat tube. As steam pass through anti-priming pipe, the water get condensed and fall back to the drum. The super-heat tube is exposed to the flue gas as shown in figure and the steam inside the tube gets superheated. The super-heated steam is then finally taken out through the main stop valve and transferred to the engine when it required.	

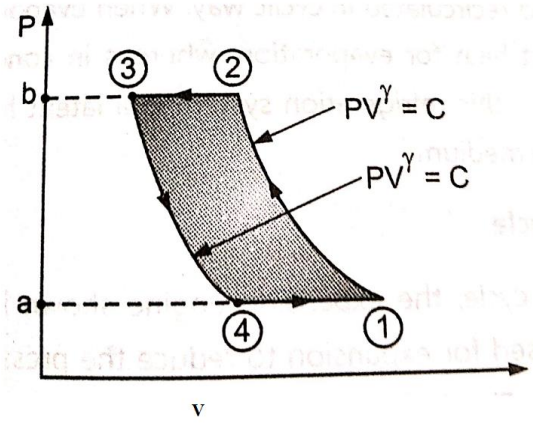
		The flue gases give up its heat to water when it passes over the tube and finally escaped to the chimney.	
4	c	**Necessity of safety valve in boiler:** The main function of a safety valve is to relieve pressure. It is located on the boiler steam drum, and will automatically open when the pressure of the inlet side of the valve increases past the pre-set pressure. The function of the Safety Valve is to protect life and property against failure to control system pressures, i.e. it offers the last means of reducing system pressure before total failure. Use to prevent the excessive steam pressure inside the boiler drum exceeding the design pressure.	4
4	d	**Electrostatic Precipitator:** 	

		An electrostatic precipitator (ESP) removes particles from a gas stream by using electrical energy to charge particles either positively or negatively. The charged particles are then attracted to collector plates carrying the opposite charge. The operation of electrostatic precipitators is simple. The dirty flue gas escaping through the smokestack is passed through two electrodes. The shape these electrodes take depends on the type of electrostatic precipitator used, but they can be metal wires, bars, or plates inside a pipe or the smokestack itself. One of the electrodes is charged with a high negative voltage, and this plate causes particulates inside the smoke to obtain a negative charge as they pass by this electrode. Further along the pipe, the second electrode carries a similarly high positive voltage. Based solely on the fact that opposite charges attract, the negatively charged soot particles are pulled towards the positive electrode and stick to it. Occasionally these plates must be cleaned to remove the accumulated soot and dispose of it into a hopper. The soot and ash collected from coal burning power plants in this manner is referred to as fly ash. Even though most electrostatic precipitators work in a similar way, there are many variations and different types that work better for different sized particles, different smoke compositions, and different amounts of pollution. The need for a variety of designs comes partly from the fact that coal burned around the world varies in its chemical composition drastically. Other power plants may look to remove certain pollutants - such as sulfur dioxide - or look to minimize the amount of ash produced. Additionally, some low-sulfur coals that are burned have a higher electrical resistivity, which makes it more	2 2

		difficult to remove the ash produced by this coal using electrostatic precipitators	
4	e	**Type industrial air used for in combustion process is Process/ Compressed air.** **Method of formation of compressed air:** Air is passed through a filter to remove suspended impurities. The filtered air is supplied to the compressor. Discharge from the compressor will be at a pressure of 100 to 150 psi, which is stored in a storage tank. The air thus obtained is called compressed or process air. 	1 2 1
5		**Attempt any two**	**12**
5	a	**Selection criteria for refrigerant** 1. It should have low boiling point and low freezing point. 2. It must have low specific heat and high latent heat. 3. It should have high critical pressure and temperature. 4. Pressure required to be maintained in the evaporator and condenser should be low enough and positive. 5. It should have low specific volume. 6. It should have high thermal conductivity.	1 mark each for any six points

		7. It should be non-flammable, non-toxic non corrosive. 8. It should not have any bad effect on the stored material or food when any leakage develops in the system. 9. It must have high miscibility with lubricating oil. 10. It should have high COP. 11. It must be readily available and cheap.	
5	b	**i) Registration of boiler** Boilers have to be registered before they can be used. The owner of the boiler shall give an application for the same. The inspector shall examine the boiler and find the maximum pressure at which the boiler may be operated. He will submit his report to the chief inspector and in turn the employer may get authorized for 1 year to use the boiler. **ii) Certificate of renewal** The certificate useful to the employer for using the boiler shall be renewed 1. After generally 12 months 2. If the boiler is transferred from one state to another. 3. If some accident occurs. 4. If some alteration are done in boiler parts. **iii)Transfer of boiler** When a boiler is transferred from one state to another, permission is again sought from the Chief Inspector of new state for its installation and operation **iv)Penalty** A fine up to Rs 500 and then Rs 1000 per day additional after the first day of the offence shall be imposed on occupier of the boiler who operate a boiler without getting it registered, refuses to surrender the certificate of operating	1.5 mark each

		the boiler, does not report the transfer of the boiler from one state to another state & uses it, does not report the accident of boiler , repair & replace boiler parts without permission	
5	c	Volume of air = 200m^3/ minute $DBT_1 = 15^0C$ RH = 75% $DBT_2 = 25^0C$ Using Psychrometric chart i)RH of heated air = **40%** ii) Wet bulb temperature of heated air = **16^0C** iii) Enthalpy corresponding to 15^0C (h_1)= 35kJ/kg Enthalpy corresponding to 25^0C (h_2)= 45kJ/kg At 15^0C, from the psychrometric chart, volume m^3/ kg dry air = 0.826 Mass of air = 200(m^3/ minute) / 0.826 (m^3/ kg) = 242.13kg/minute Heat added to air per minute = $\dot{m}$(h_2- h_1) = 242.1(45-35) = **2421kJ**	 2 2 2
6		**Attempt any TWO of the following**	**12**
6	a	Cp(air) = 1.03kJ/kg γ= 1.4 R = 0.287kJ/kg	



Process 1-2: Compression

P_1 = 1 atm

T_1 = -6 +273 = 267K

P_2 = 5atm

$T_2 = T_1 * \left(\frac{P_2}{P_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} = 267 * \left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}} = 422.87K$ 1

Process 2-3 :Cooling at constant pressure

P_3 = 5atm

T_3 = 12 +273 = 285K

Process 3-4: polytropic process

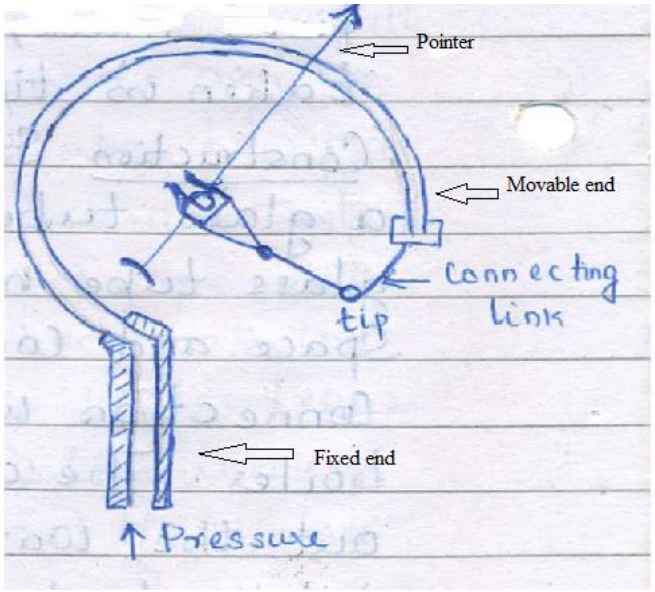
P_4 = 1 atm

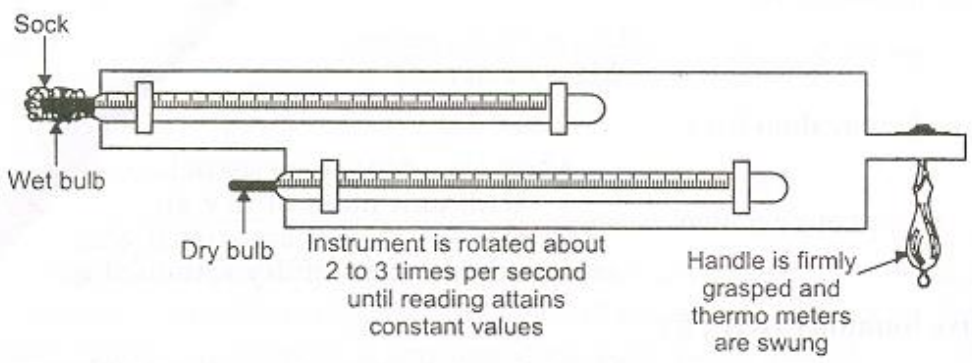
$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\left(\frac{n-1}{n}\right)}$

$\frac{285}{T_4} = \left(\frac{5}{1}\right)^{\frac{1.3-1}{1.3}}$ 1

T_4 =196.58K

Work done on the air in compressor = Area 1-2-b-a = $R*(T_2-T_1)* \gamma / (\gamma-1)$

		= 0.287 *(422.87-267) *(1.4/1.4-1) = 156.57kJ/kg Work done by air in expansion = Area 3- 4-a-b = $R*(T_3-T_4)* n / (n-1)$ = 0.287*(285-196.58)*1.3/(1.3-1) = 109.96 kJ/kg Net work done on air (W)= 156.5-109.96 = **46.54kJ/kg** Heat abstracted (RE) = $Cp(T_1-T_4)$= 1.03(267-196.58) = 72.53kJ/kg COP = RE / W = 72.53/46.54 = **1.558**	2 2
6	b	**Pressure Gauge** **Diagram**  **Explanation** C shaped bourdon gauge consists of C shaped bourdon tube, tip, adjustable link, segment lever, sector, pinion, spring and pointer. The bourdon tube is a thin walled tube having non circular cross section. One end of the tube is welded or soldered at the base (fixed end) through which pressure is fed inside	3 marks for diagram, 3 marks for explanation

		the tube, while the other end (free end) is sealed by a tip. When the fluid under pressure enters the bourdon tube, its cross section tends to become more and more circular that causes straightening of the tube. Since one end of the tube is fixed, straightening of the tube causes the free end to deflect, which is called as tip travel. The linear motion of the tip moves the pointer on a scale calibrated in terms of pressure	
6	c	**Sling Psychrometer** **Diagram**  **Explanation** Sling psychrometer consists of a dry bulb thermometer and a wet bulb thermometer mounted side by side in a protective case that is attached to a handle by a swivel connection so that the case can be easily rotated. Dry bulb thermometer is exposed to air and measure the actual temperature of air. The bulb of the wet bulb thermometer is covered by a wick thoroughly wetted by distilled water. The temperature measured by this wick covered bulb of the thermometer is the temperature of water in the wick and is called WBT. Sling psychrometer is rotated in the air for 1 minute after which the readings of both the thermometers are taken.	3 3