SUMMER-17 EXAMINATION

Model Answer

Subject Title: Fundamentals of Chemical Engineering Subject code : 17206

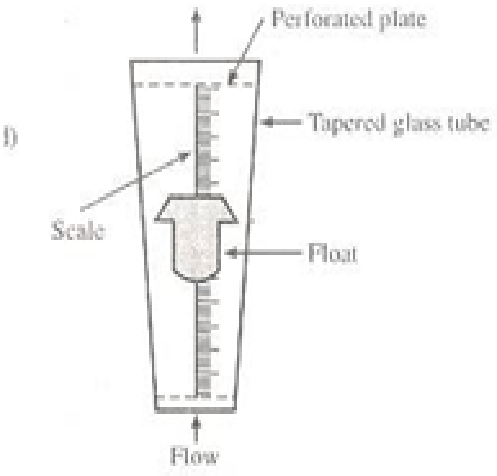
Important Instructions to examiners:

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.

Q No.	Answer	marks
1	Any ten	20
1-a	**Density:** Unit: Kg/m^3 **Force**: Unit: Newton(N)	1 1
1-b	Molecular weight of Na_2CO_3 =(23*2)+12+(16*3) =**106**	 1 1
1-c	**Unit operations used for separation of solid- liquid mixture:** 1. Sedimentation 2. Filtration 3. Centrifuging	1 mark each for any 2
1-d	**Volumetric flow rate:** It is the volume flowing per unit time Volumetric flow rate = Volume/ time **Instrument used to measure volumetric flow rate(any one)** 1. Rotameter 2. Venturi meter 3. Orifice meter	1 1
1-e	(i) **Density:** Density is mass/ volume (ii) **Specific gravity:** It is the ratio of density of a liquid to density of water at 4^0C	1 1
1-f	$1kg/m^3$ $1m^3$=1000 lit $1kg/m^3$ = 1/ 1000	 1

	= 0.001 Kg / lit	1
1-g	**Oxidation:** It is defined as the addition of oxygen or removal of hydrogenation from organic compounds. - Oxidation reaction may involve the introduction of oxygen in the molecule of a compound. Oxidation of acetaldehyde: $CH_3CHO + ½ O_2 \longrightarrow CH_3COOH$ Acetaldehyde acetic acid - Oxidation reaction may involve the removal of hydrogen from the molecule of a compound.	1 1
1-h	**Uses of Sulfuric acid(any 2)** a) It is used as a dehydrating agent drying agent acidifying agent and neutralizing agent. b) It is used in the manufacture of fertilizer. c) Sulphuric acid is used for pickling iron and steel before galvanizing. d) It is used in processing metals. e) It is used in the manufacture of lead acid batteries.	1 mark each
1-i	**Unit Process and unit operation:** **Unit process** | **Unit operation** Chemical changes takes place | Physical changes takes place, Chemical reactions involved | no chemical reactions involved Eg; oxidation, reduction, nitration, sulphonation | Eg; drying, distillation, mechanical separation	1mark each for any 2

1-j	**Ball mill:**  **Jaw Crusher** 	1 1
1-k	$^0F = 1.8\ ^0C + 32$ $= 1.8 * 20 + 32$ $=$ **68** ^0F $^0K = {}^0C + 273$ $= 20 + 273$ $=$ **293 K**	 1 1
1-l	**Principles of size reduction**: 1. Compression (Crushing) 2. Impact (Grinding) 3. Attrition/ Rubbing(Ultra fine grinding) 4. Cutting	½ mark each
2	**Any four**	16
2-a	**Dalton's law:** Daltons law states that total pressure of a gas mixture is equal to the sum of partial pressures $P=P_1+P_2+P_3$	2

	where P is total pressure of gas mixture and P_1,P_2,P_3 are partial pressures **Amagat's law**: Amagats law states that total volume of a gas mixture is equal to the sum of pure component volumes $V=V_1+V_2+V_3$ where V is total volume of gas mixture and V_1,V_2,V_3 are pure component volumes.	2
2-b	Weight of NaOH = 100 kg Molecular weight of NaOH = 40 k moles of NaOH = weight / mol;.wt = 100/40 = **2.5**	1 1 1 1
2-c	**Rotameter:**  	4
2-d	**Unit operation used for Size separation is screening.** **Screening:** It is a method of separating solid particles according to size alone by means of screens of known aperture. Sieves and screens are used industrially	1

	for the separation of solid particles according to their sizes, for production of closely graded materials and for carrying out size analysis. In industrial screening, solids are dropped on a screening surface. The material retained on the screen surface are called oversize material, while materials passing through screen are called undersize particle. A single screen can make the separation of material into two fractions. **Importance of screening:** i) Separation of fine from feed material. ii) To produce material of specific size limits.	3
2-e	**Gas Absorption:** -This operation is used to separate the components of gas mixture . -It is carried out for the recovery or the removal of a soluble components of a gas mixture depending upon the situation. -Absorption is an operation in which a gas mixture is contacted with a liquid solvent for the purpose of dissolving a definite component of the gas mixture in the liquid. Example: 1) Absorption of ammonia from an air- ammonia mixture by water 2) Removal of hydrogen sulfide from naturally occurring hydrocarbon gases.	4
2-f	**Modes of heat transfer are:** Conduction Convection Radiation 1. Conduction: It is the transfer of heat without the movement of particles. Eg: heating of a metal rod 2. Convection: It is the transfer of heat within a fluid by the actual	1 1 1

	migration of particles of hot fluid with cold fluid because of change of density of molecules of fluid by application of heat. Eg. Boiling of liquid 3. Radiation: It is the transfer of heat through space by electromagnetic waves. When radiation passes through matter, it is transmitted, reflected or absorbed. Eg. Transport of energy from the sun to earth.	1
3	**Any 4**	16
3-a	**(i) Molality:** Molality = gmmole of solute/ weight of solvent in kilogram **(ii) Normality:** N = gmequivalent of solute/ volume of solution in liter	2 2
3-b	Weight of NaOH = 100 kg Weight of Na_2CO_3 = 200 kg Total weight = 300 kg Weight % of NaOH = (100/ 300) * 100 =**33.33%** Weight % of Na_2CO_3= (200/ 300) * 100 = **66.67%** Molecular weight of NaOH = 40 Gram moles of NaOH = 100/40 = 2.5 Molecular weight of Na_2CO_3 = 106 Gram moles of Na_2CO_3 = 200/106 = 1.89 Total moles = 2.5+1.89 = 4.39 Mol % of NaOH = (moles of NaOH / Total moles)*100 = (2.5/ 4.39)*100 = **56.95%** Mol % of Na_2CO_3 = (moles of Na_2CO_3/ Total moles)*100 = (1.89/ 4.39)*100 = **43.05%**	1 1 1 1

3-c	Weight of NaOH = 80 gms. Gram equivalent of NaOH = 80/40 = 2 Volume of solution = 3000ml= 3 lit N = gmequivalent of solute/ volume of solution in liter = 2/3 = 0.667 Normality of the solution = **0.667 N**	 1 1 1 1
3-d	**Distillation:**-Distillation is an operation in which the components of a liquid mixture are separated using thermal energy. It depends upon the difference in boiling points of the individual components. The difference in vapour pressure of the components of a liquid mixture at the same temperature is responsible for separation by distillation. In this operation, liquid and vapour phases are involved. The vapour phase is created by supplying heat to the liquid phase. The concentration of more volatile component of the liquid mixture is higher in vapour phase than in the feed solution, while that of the less volatile component is higher in the liquid phase. When a liquid mixture containing more volatile and less volatile components are heated, more volatile component will vaporize first and the vapours are collected and condensed to get it in pure form.	4
3-e	**(i)Chlorination:** It refers to the process in which one or more chlorine atoms are introduced into an organic compound. **Chlorination of methane:** Chlorination of methane in presences of ultraviolet light or at a temperature of 300 – 400 C results in the formation of polyhalogen derivatives. U.V.light $CH_4 + Cl_2$ ----------> $CH_3Cl + CH_2Cl_2 + CHCl_3 + CCl_4 + HCl$ 300-400 C	 1 1

	OR **Manufacturing of Chlorobenzene:** Benzene reacts with chlorine gas in the presence of catalyst at about 30-60 ^oC to form chlorobenzene $C_6H_6 + Cl_2 \xrightarrow[30\text{-}60^oC]{FeCl_3} C_6H_5Cl + HCl$ Benzene Chlorobenzene **Note : Any other suitable example** **(ii) Nitration reactions** : It is the reaction with nitrating mixture to introduce nitro(NO_2) group into an organic compound. $C_2H_6 + HNO_3 \text{------>} C_2H_5NO_2 + H_2O$	1 1
3-f	**Esterification reaction:-**The reaction of an alcohol with a carboxylic acid to produce an ester is termed as esterification. Esterification of an acid such as acetic acid by an alcohol such as ethyl alcohol results in the production of ethyl acetate. Sulphuric acid and hydrochloric acids are the catalysts used for esterification. **Chemical Reaction for esterification:** $CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$ Esterification is the reaction where ester is produced whereas saponification is a reaction where sodium salt of ester is produced.	2 2
4	**Any 4**	16
4-a	**Advantages of size reduction** : 1. Easy handling 2. Easy transportation 3. Increase in reaction rate	1 mark each for any 4

	4. For having intimate mixing of solid 5. To separate various ingredients.	
4-b	**(i)Partial Pressure:** Partial pressure of a component gas is the pressure that would be exerted by that component gas if it alone was present in the same volume and at the same temperature as the gas mixture. **(ii)Vapor pressure** : It is the pressure exerted by vapor on the surface of liquid at equilibrium conditions. OR It is the absolute pressure at which the liquid and its vapour are in equilibrium at a given temperature.	2 2
4-c	N = gmequivalent of solute/ volume of solution in liter 0.5= gmequivalent of solute/ 0.25 lit Gram equivalent of H_2SO_4 = 0.125 weight of H_2SO_4 = 0.125*49 = 6.125gram To prepare 0.5N, 250 ml H_2SO_4 solution, dissolve 6.125grams H_2SO_4 in water to get 250ml solution.	1 1 1 1
4-d	**Drying:** Drying is an operation in which the moisture of a substance is removed by means of thermal energy. In this operation, moisture is removed by circulating hot air or gas over the material in order to carry away the water vapour. In this operation, heat and mass transfer occur simultaneously. Heat is transferred from the gas phase to the solid phase and mass is transferred from the solid phase to the gas phase. Usually a solid or nearly solid materials are processed in dryer. Drying operations may be carried out for i)reducing the transportation cost, ii)making materials more suitable for handling and storage, iii)preventing	4

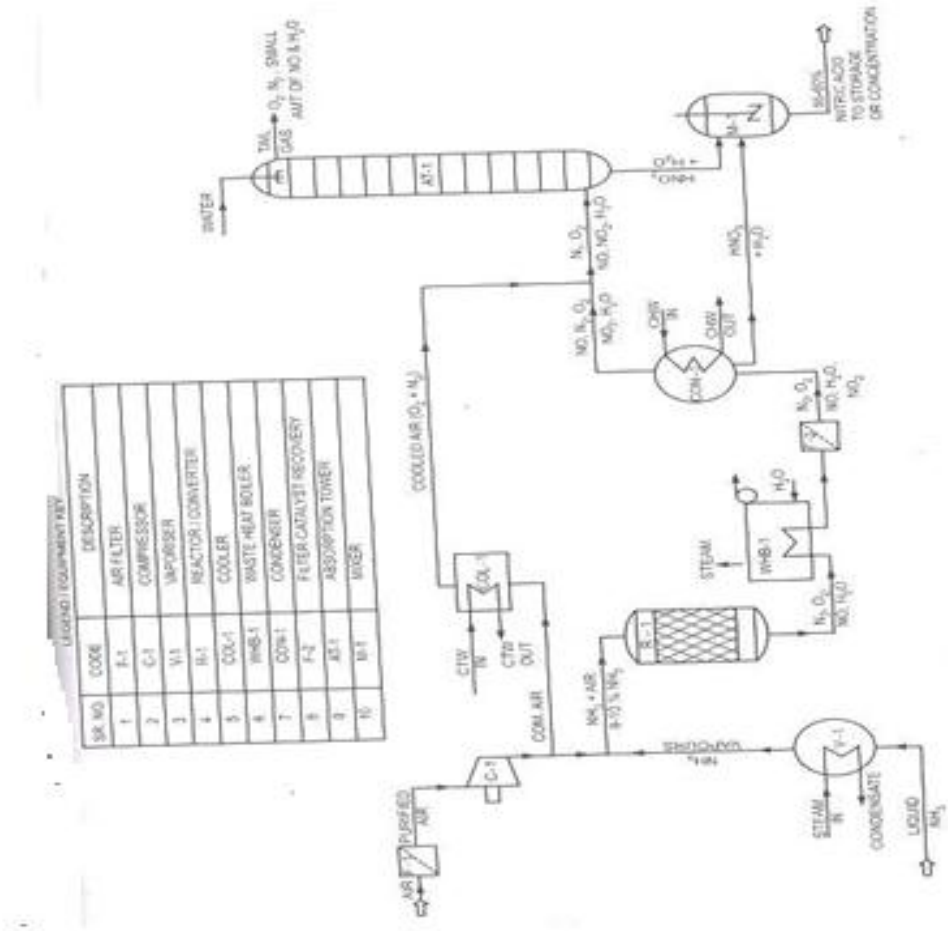
<table>
<tr><td></td><td>corrosion arising due to the presence of moisture and iv)providing definite properties to materials.
Eg: Drying of pharmaceuticals, dyes, paper, cloth</td><td></td></tr>
<tr><td>4-e</td><td>Different types of pumps and their applications:
<table>
<tr><th>Pump</th><th>Application</th></tr>
<tr><td>Centrifugal pump</td><td>For handling thin liquids and suspension of solids in liquids</td></tr>
<tr><td>Gear pump</td><td>For handling high viscosity liquids</td></tr>
<tr><td>Diaphragm pump</td><td>For handling corrosive liquids</td></tr>
<tr><td>Screw pump</td><td>Handling slurries containing higher proportions of solids</td></tr>
</table></td><td>2 marks each for any 2</td></tr>
<tr><td>4-f</td><td>Sulfonation reactions :
It is the reaction with sulfuric acid to introduce sulfonic (SO_3H) group into a compound.
$C_6H_6 + H_2SO_4 \text{----}\rightarrow C_6H_5SO_3H + H_2O$
Benzene benzene sulfonic acid</td><td>2

2</td></tr>
<tr><td>5</td><td>Any 4</td><td>16</td></tr>
<tr><td>5-a</td><td>Hydrogenation: It refers to the chemical reaction of an organic compound with molecular hydrogen in the presence of a catalyst.
Chemical Reaction for hydrogenation:
$CH_2= CH_2 + H_2 \rightarrow CH_3\text{-}CH_3$
$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$
Hydration: It refers to a unit process of adding a water molecule to an Organic Compound.</td><td>1

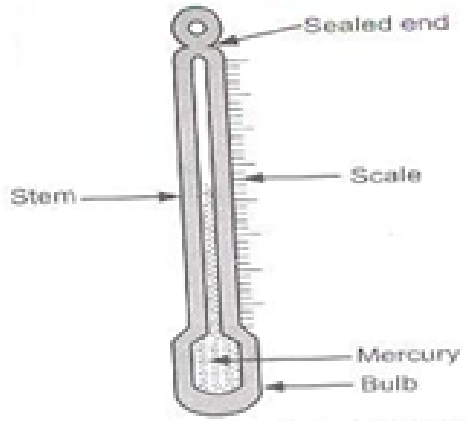
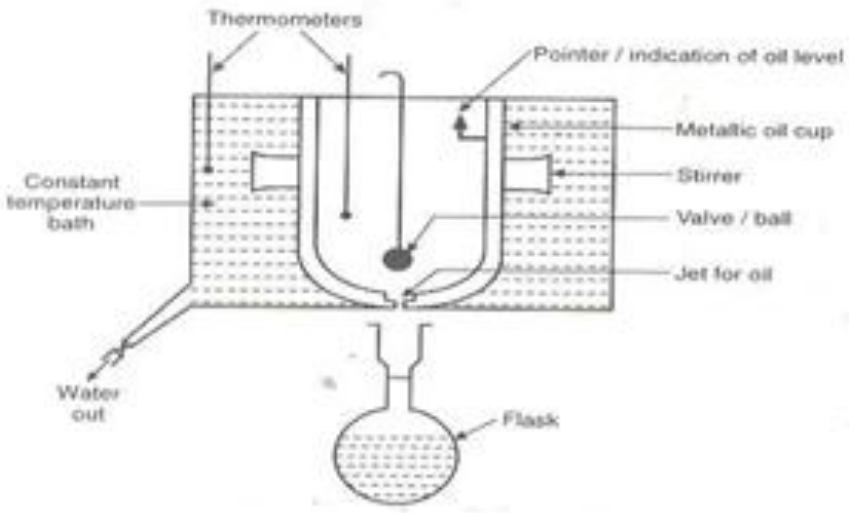
1

1</td></tr>
</table>

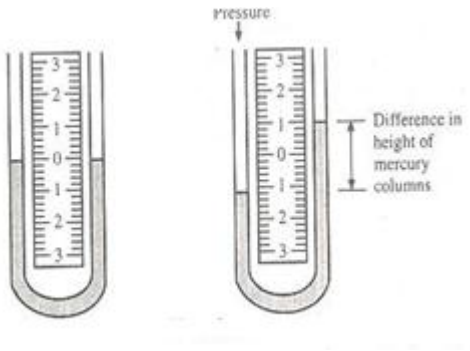
<table>
<tr><td></td><td>Hydration of Ehtylene :
Ethanol can be produced by hydration of ethylene in presence of a phosphoric acid at about 300^{o}C
$C_2H_4 + H_20 \xrightarrow{H_3PO_4} C_2H_5OH$
Hydration of propylene :
$CH_3CH = CH_2 + H_2O \xrightarrow{} CH_3CH(OH)CH_3$
Or any other example student can write</td><td>1</td></tr>
<tr><td>5-b</td><td>Differentiate between filtration and sedimentation
<table>
<tr><th>Sedimentation</th><th>Filtration</th></tr>
<tr><td>Gravitational force is acting</td><td>Pressure force is acting</td></tr>
<tr><td>Sedimentation tanks or settling tanks are used.</td><td>Filters are used</td></tr>
<tr><td>No filter medium is used</td><td>Filter medium is used</td></tr>
</table></td><td>2 marks each for any 2</td></tr>
<tr><td>5-c</td><td>Flow sheet for manufacturing of Nitric acid:</td><td>4</td></tr>
</table>

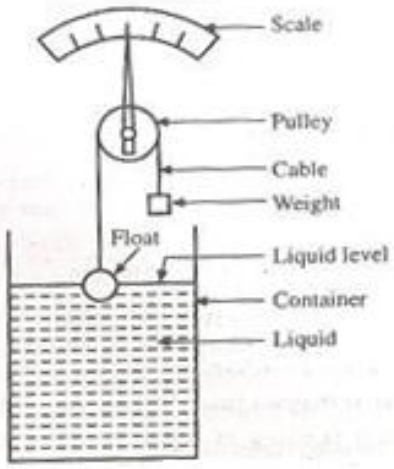
		
5-d	**Saponification:** The alkaline hydrolysis of an ester to form sodium salt and alcohol is referred to as saponification. $CH_3COOC_2H_5 + NaOH$ ---------> $CH_3COONa + C_2H_5OH$ Ethyl acetate sodium acetate	2 2
5-e	**Manufacturing process of sulfuric acid:** Sulfuric acid is produced by contact process. Fresh air is fed continuously to an air drying tower with the help of an air blower. Molten sulphur and dried air are fed to a sulphur burner where sulphur is oxidized to sulphur dioxide. The	4

	burner outlet gas containing 8-10% SO_2 are then cooled in a waste heat boiler from 1000^0C to 450^0C and are then introduced into a catalytic converter employing vanadium pentoxide catalyst. In the converter SO_2 gets oxidized to SO_3 at about 450^0C. The oxidation is exothermic and heat evolved during the course of reaction may be removed by using water to generate steam. The product gas containing SO_3 from the converter is then cooled in a heat exchanger followed by a cooler and then fed to an absorber where SO_3 is absorbed in 97% sulfuric acid. The acid leaving the absorber of 98% strength is then cooled in a double pipe type chiller and finally goes to an intermediate storage tank from which product sulfuric acid is send to bulk storage. The acid of 98% strength from the intermediate storage tank is fed fed to the air drying tower for drying air. The acid of strength 97% from the drying tower is fed to the absorber for absorption of SO_3.	
5-f	**Sedimentation:** The separation of solids from a suspension in a liquid by gravity settling is called sedimentation. The force responsible for sedimentation is **gravitational force**. In this operation, a dilute slurry is separated into the clear liquid and slurry of high solid contents. The simplest method of removing the suspended impurities from a liquid is by plain sedimentation. In the treatment of water, water is allowed to stand undisturbed or move very slowly through the basin until the suspended impurities settle to the bottom and relatively clear liquid is drawn off the top. Dorr thickener is the common equipment used for sedimentation. **Application:** Removal of solids from liquid sewage waste, removal of suspended impurities from water.	4
6	**Any 4**	16
6-a	**Mercury thermometer:** **Construction:**	2

	It consists of a glass stem having fine capillary and glass bulb. The bulb is at lower end of glass stem. Mercury is filled in the bulb; after filling, open end of capillary is sealed under vacuum so that no air is left in capillary.  	2
6-b	**Redwood Viscometer:**  	4

6-c	**Personal protective equipments used in Chemical industries (any 4)** The purpose of PPE is to provide a safety barrier a hazard and the body of a person working in a hazardous environment. **1) Hard hat** : It is used for protection of head **2) Safety goggles :** It is used for protection of eye **3)Safety shoes:** It is used for protection of legs and foot **4)work clothes:** It is used for protection of whole body **5)Ear muff:** It is used for protection of ear **6)Ear plug :** It is used for protection of ear **7)Guard cuff's :** It is used for protection of body **8)Face Shield:** It is used for protection of face	1 mark each
6-d	**Determination Density of a liquid using Specific gravity bottle:** 1) In order to determine the density by specific gravity bottle, first weigh the clean, dry, empty and stoppered bottle. 2) Then fill the bottle completely with the liquid ,stopper it ,clean the bottle from the outside with blotting paper to remove the excess liquid that spills on it outside 3) Weigh it again. Mass/Weight of empty bottle = W_1 g Mass/Weight of bottle filled with liquid = W_1 g Mass/Weight of the liquid = $W_2 - W_1$ Volume of the specific gravity bottle = V ml	4

	Density of the liquid in g/ml = $\frac{\text{Mass}}{\text{Volume}} = \frac{W_2 - W_1}{V}$ To avoid error due to the volume ,a certificate regarding the exact, accurate volume of the bottle should be taken from the supplier	
6-e	**U tube manometer**:  **Construction:** It consists of a small diameter U shaped glass tube. The tube is clamped on a wooden board and between two arms or legs of the manometer, a scale is fixed on the same board. On the scale, the zero is marked at the center. The manometric fluid is poured into the tube until the level in both the arms reaches the zero mark. The manometric fluid should be immiscible with the process fluid and heavier than process fluid. **Working :** 1)The pressure in the inlet line can be measured by connecting it by plastic tubing to one of the arms of the U-tube. 2) By measuring the difference in the height of the fluid in two arms of the U-tube pressure can be measured by the equation. $\Delta P = P_1 - P_2 = h(\rho_m - \rho)\, g$	1 1.5 1.5

	Where , ΔP= Pressure difference, h= difference in levels of two arms ρ_m= density of manometric fluid	
6-f	**Float and tape method:** It consists of a float which is a hollow metal ball. It is connected to a light weight cable , the other end of the cable is connected to a counter weight. The cable is wound around a pulley, to which an indicating pointer is attached. The movement of the float is thus transferred to the pointer, which indicates the level of liquid. Because of the buoyancy, the float will follow the changing level of the liquid. As the level rises or falls, the movement of the float is transferred to the pointer that indicates the level. It is a continuous direct level measurement used in open vessels/ containers.  	4