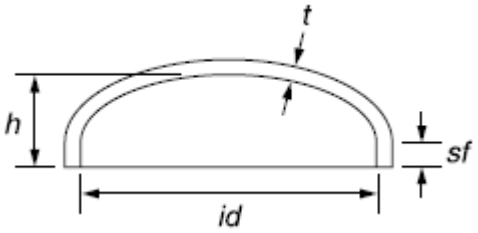
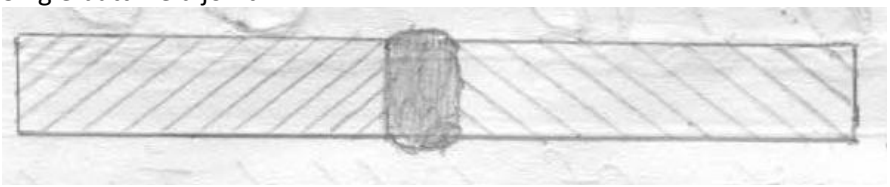
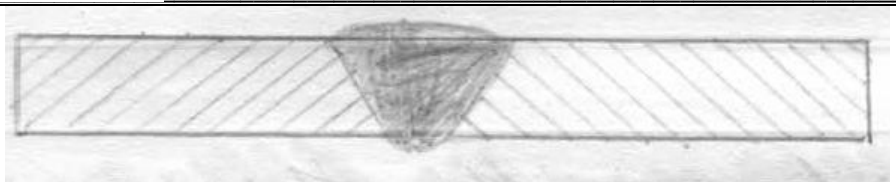
SUMMER – 15 EXAMINATIONS

Subject Code: **17457** **Model Answer**

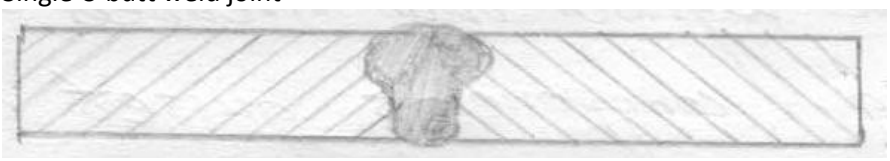
Important Instructions to examiners:

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 judgment 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.

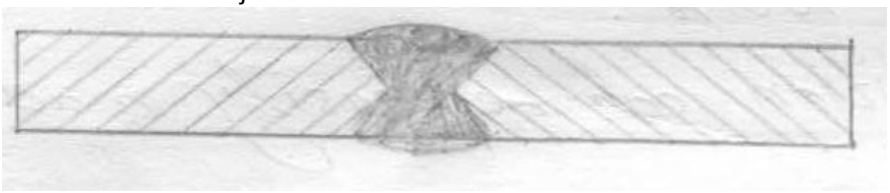
Q. NO.	MODEL ANSWER	MARKS	TOTAL
1	**Attempt any Five of the following**	**5 x 4**	**20**
a)	A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. Pressure vessels are leak proof containers. They may be of any size, shape and range. Pressure vessels are classified as; Function: Storage tank, Process vessel, Reactor, Heat Exchanger, etc. Geometry: Cylindrical, Spherical, Conical, Non circular, Horizontal, Vertical, etc. Construction: Monowall, Intersecting, Multishell, Cast, Forged, etc. Service: Cryogenic, Steam, Vacuum, Fired/Unfired, Stationery/Mobile, etc.	**02 marks** **02 mark for any 02 classification**	04
b)i)	Dead load: They are loads due to weight of vessel itself and any part permanently connected with vessel.	**02 marks**	04
b)ii)	Piping load: It is that compressive/tensile load on the pressure vessel consisting of the weight of pipe sections supported by nozzles into the vessel shells and the load due to thermal expansion of pipes.	**02 marks**	
c)	Semi Elliptical Head:  	**04 marks**	04
d)	Stress concentration: Whenever in a part there is a change in the shape of its cross-section, then the stress distribution changes. This irregularity in the stress distribution caused by the abrupt changes of form is called as stress concentration. It occurs because of stresses in the presence of notches, fillets, holes, keyways, splines, surface roughness, shoulders, scratches, etc.	**02 marks** **02 mark for any two causes**	04
e)	Single butt weld joint  Single V butt weld joint	**04 marks for any four joints (01 mark for each)**	04



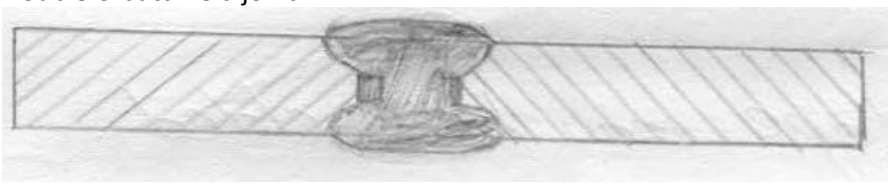
Single U butt weld joint



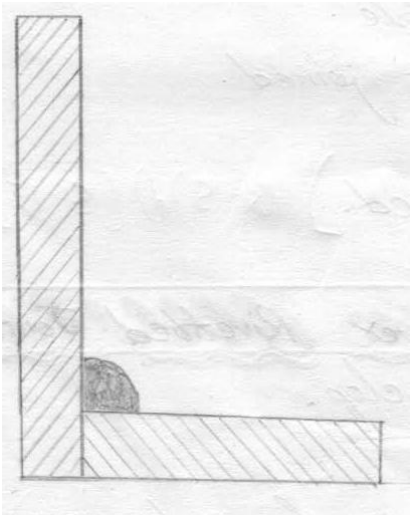
Double V butt weld joint



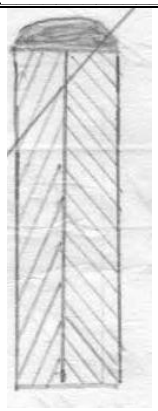
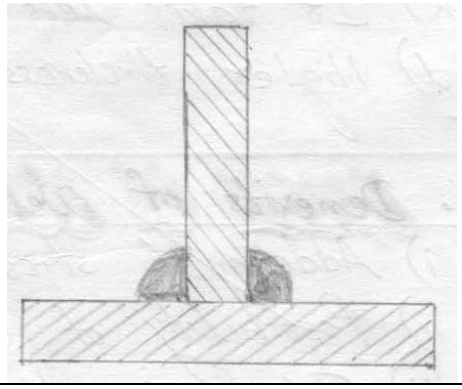
Double U butt weld joint

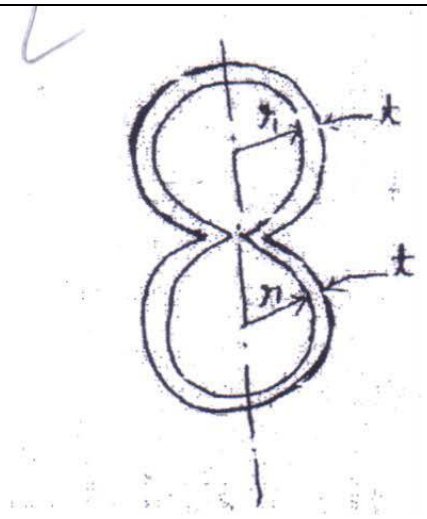


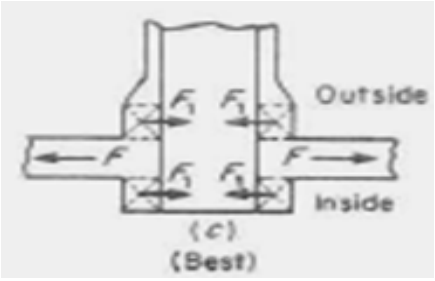
Corner Joint



Edge joint

	 T- Joint 		
f)	(1) Austenitic Stainless Steel: It contain Iron + 6% to 22% Ni + 16 to 26% Cr (2)Martensitic Stainless steel: It consist of 0.1% - 0.6% carbon + 1.25% - 2.5%Ni + 11% Cr. (3)Ferretic Stainless steel: It contains 13% - 30% Cr (4) Ferretic Austenitic Stainless steel: It contains 5% Ni + 26% Cr (5)Nitrogen Added Stainless Steel: 0.15% - 0.20% Nitrogen is added in stainless steel.	**04 marks for any four materials (01 mark for each)**	04
g)	Design consideration features for pressure vessel: 1. Proper selection of Factor of Safety 2. Proper material selection 3. Need of heat treatment 4. Economy 5. etc.	**04 marks for any four (01 mark for each)**	04
h)	Methods of attaching protective coatings: 1. Integral cladding Low carbon steels or low alloy steels (base plates) also called as backing plates and corrosion resistant steel (liners) are welded at the edges. This is then passed through steel mills for hot rolling operations. The high temperature and high pressure creates a solid bond between the plates. Thickness of the liners is about 2mm to 4mm or 8% to 20% thickness of base metals.	**04 marks for any two methods**	04

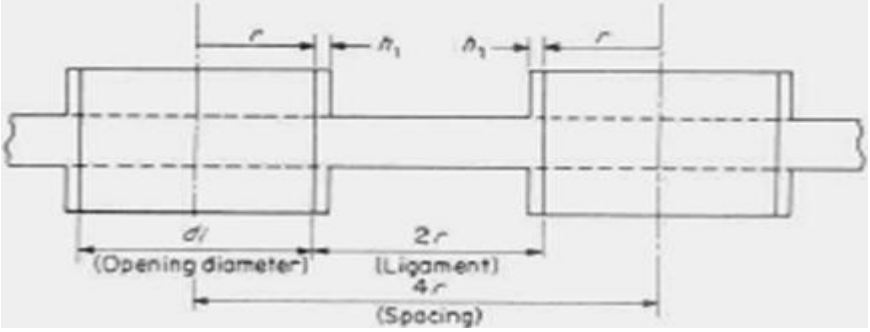
	2. Sheet lining The corrosion resistant layer is attached to a vessel shell by welding. Thickness of sheet is 2mm to 4mm. Types are; i) Strip type lining of 3' to 5' X 3" to 6" wide strips are welded on base material by spot welding. ii) Sheet type lining of several feet in length and width are welded on base materials by spot, plug or seam welding. The linings are attached to the vessel after the vessel is entirely completed. Sometimes sheets are attached to the base plates before rolling or forming. Carbon steel surfaces (base plates) are ground to provide suitable surface for application of the liner. 3. Protective coatings Coatings should be applied only on clean surfaces free from grease, oil, dirt, scale, etc. i) Metallic coatings – Common methods are electroplating, mechanical cladding (most important), metal spraying, cementation, hot dipping, and condensation of metal vapors. ii) Inorganic coatings – Chemical dipped methods are used to create protective oxide films on iron, steel, stainless steel, copper, aluminum and some of their alloys. Such films are very thin and colored. e.g. Electrolytic coating iii) Organic coating – Different synthetic resins, pigments, oils and solvents are used in coating formulations. A continuous adherent inert film is formed between the metal and environment. They change the appearance of the metal e.g. paint enamel, lacquer.		
2	**Attempt any <u>Two</u> of the following**	**8 x 2**	**16**
a)	 The sphere is an ideal pressure vessel because, • Storage wise it contains the largest volume with minimum surface area.	**02 marks for diagram** **$1^1/_2$ marks for each advantage**	**08**

	• It is having less stress value because of uniform pressure distribution. • It has minimum surface area and minimum thickness and hence less material weight and cost. • When requirement exceeds those possible or practicable for single sphere, then multiple intersecting spheres can be used. • Intersecting sphere has a practical application in the economical design of vessels for extremely high pressure.		
b)	Given data: P= 1.5MPa = 1.5N/mm^2 Di= 4m, Ri= Di/2=2m=2000mm E= 80% = 0.8 S= 160MPa = 160N/mm^2 Apex Angle =55^0 Therefore, α= (½) x 55^0 = 27.5^0 =27.5^0 X (π/180) =0.479 radians. To find (i)thickness of shell (ii)Thickness of conical head Calculation: (i) t= PRi/(SE - 0.6P) = (1.5 x 2000)/{(160 x 0.8) – (0.6 x 1.5)} = 23.60mm appro ≈24mm(thickness of cylindrical shell) (ii) t={ PRi/(SE- 0.6P)} x {1/ cos α } = 24 x (1/cos0.479) = 24 x 1 = 24mm (thickness of conical head)	**04 marks** **04 marks**	**08**
c)	Nozzle reinforcement is a means to provide compensation for weakening due to the hole made on the shell by providing sufficient additional materials. The reinforcing material being placed adjacent to the hole such that it should not introduce any stress concentration. Nozzle placement: 1. Single nozzles Minimum stress concentration factor is obtained with balanced reinforcement explainable by the fact that reinforcing material evenly disposed both inside and outside of the vessel surface introduces no eccentricity or unbalance to create local bending moments and stresses.  	**01 mark** **02 mark**	**08**

2. Multiple nozzle arrangements

Multiple reinforced nozzle arrangements require special consideration when they are very closely spaced because their individual effects become overlapping and the average membrane stress in the vessel wall is not increased by the presence of reinforced nozzles.

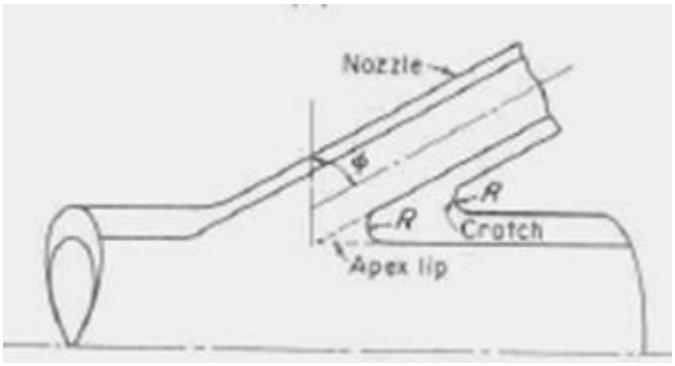
02 mark



3. Non radial nozzles

A non-radial nozzle may be installed for a functional purpose and not commonly used. A non-radial circular nozzle makes an elliptical opening in the vessel and just as an elliptical hole in a plate gives rise to a higher stress concentration factor than does a circular hole, so does a non-radial nozzle have higher stress concentration factor than its comparable radial one.

02 mark



Nozzle shape:

Nozzles may be circular, elliptical or oval in shape

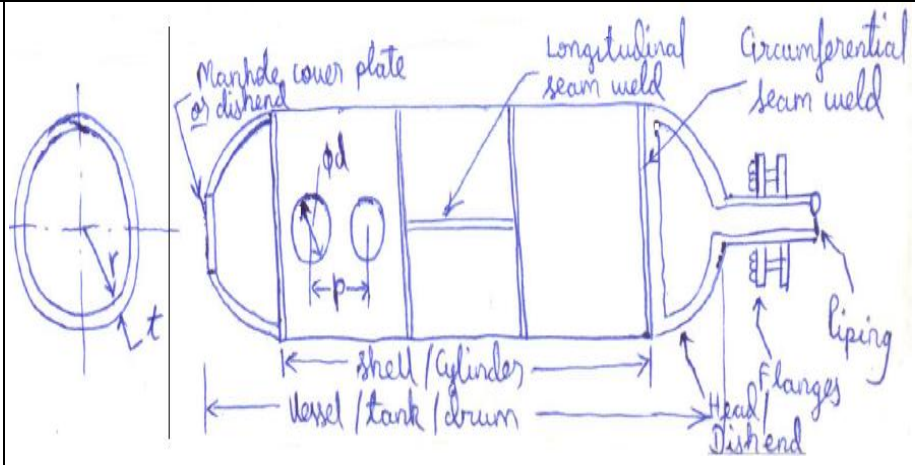
01 mark

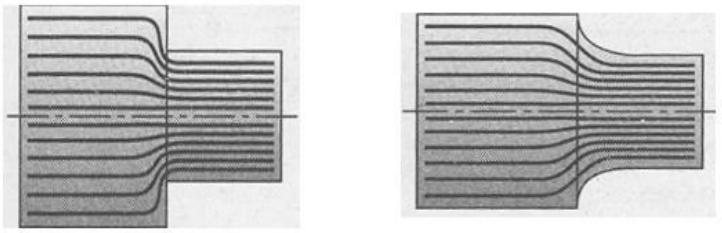
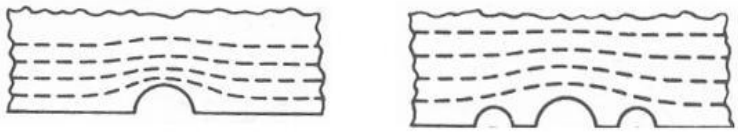
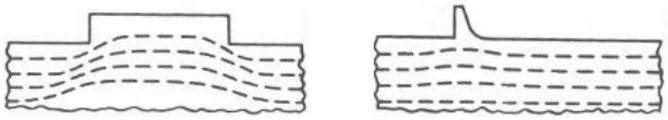
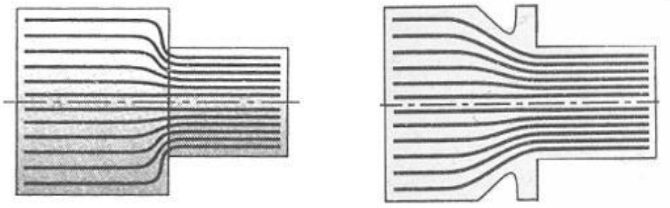
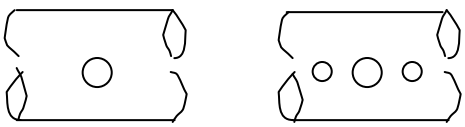
b/a	Kt
1	2.5
2	4.5
3	6.5
1/2	1.5
1/3	2.5
1/4	3.5
1/5	4.5

2b = Major axis and 2a = Minor axis

Where, b/a = 1 refers to circular opening

b/a = 1/2 refers to vertical ellipse with least stress concentration, Kt

3	**Attempt any Four of the following**	**4 x 4**	**16**
a)	 Pressure vessel consists of basic parts such as; Cylinders/shell, Rings, Baffle plates, Curved shape dish ends/ heads/ closure ends Nozzles, Flanges, Pipings, etc.	**02 marks** **02 mark**	**04**
b)	For obtaining bolt size number the design procedure of pressure vessel is as follows; 1. Number of bolts; $n = D / 600$ where, n = number of bolts D = Outer diameter of skirt = Outer diameter of shell + 2 * thickness of skirt The number of bolts will be even number and minimum 04 nos. 2. Size of bolts; $W = \prod/4 * dc^2 * fc * n$ where, W = Weight of vessel with its content dc = core diameter of bolt fc = crushing stress of bolt material n = number of bolts Now, Size of bolt, $d = dc / 0.84$ The size of bolts will be even number and minimum of M24 (The above procedure is carried out considering skirt diameter, if students follow procedure considering any other part of pressure vessel then also it is acceptable)	**02 marks** **02 marks**	**04**

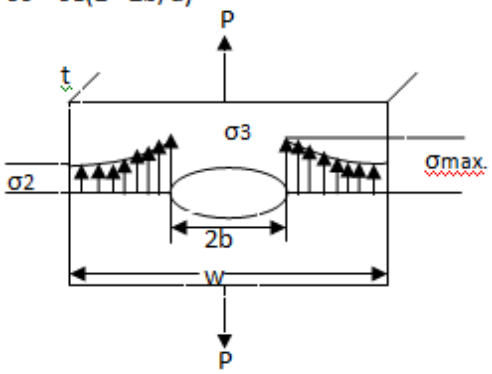
c)	Methods of reducing stress concentration 1.  (a) Force flow around a sharp corner — Force flow around a corner with fillet: Low stress concentration. 2.  (b) Force flow around a large notch — Force flow around a number of small notches: Low stress concentration. 3.  (c) Force flow around a wide projection — Force flow around a narrow projection: Low stress concentration. 4.  (d) Force flow around a sudden change in diameter in a shaft — Force flow around a stress relieving groove. 5. Steep and sharp corners be eliminated  6. Selecting materials which are tolerant to cyclic loading (ductile /tough materials) 7. 	**04 marks for any 02 methods (02 marks for each method)**	**04**

	8. Specifying manufacturing processes to provide fatigue resistance (Peening /shot blasting/Cold Working) 9. Specifying heat treatment to provide fatigue resistance- (Carburising /Nitriding) or Overdesigning part to reduce stress Levels.		
d)	Materials used for construction of vessel for non corrosive services are: i) Chromium- Molybdenum Alloy Steel: -These are suitable for temperature from 800^{o}F up to 1200^{o}F -These are suitable for high temperature high pressure conditions -It contains 9% carbon and 1% Molybdenum -It resists oxidation and hydrogen attacks ii) Stainless Steel: -Stainless Steel is the corrosion resistant material used for pressure Vessels -It contains chromium as a major non corrosive ingredient. -For heat exchangers small diameter pipes(tubes) where internal Insulation is not possible, stainless steel is used iii) High Silicon Cast Iron with Nickel and Copper: -It is also called as Haste alloy -It has good mechanical properties -It has good resistance to organic compounds -It has good corrosion resistance iv) Gray Cast Iron: - Compressive strength is 3-4 times the tensile strength - It is resistant to acid or acidic solution. - Used for component (part) which are complex to fabricate. - It is used where resistance to corrosion or abrasion (wear out) is desired. - v) High silicon Cast Iron: - Hard and brittle. - Absorb shock - Corrosion resistance. - Unaffected by sulphuric acid, nitric acid and chlorine containing chemical. vi) Nickel alloy cast Iron: - It contains high nickel + Copper + Chromium - They are corrosion resistant, wear resistant and heat resistant. - They have good strength, toughness, good castability and good machinability. - Alkalies and natural salt solution are handled by this material.	**04 marks for any 04 materials (01 mark for each material)**	**04**

<table>
<tr><td></td><td>vii)Alloy steel:
Steel with alloying element like Ni,Cr,,Sn,Mo,Mn,Be,Vn,Titanium,Co etc is called as alloy steel.
- Mn is used for improving abrasion resistance,toughness and elasticity.
- Ni and Cr are used for corrosion resistance and high temperature resistance.
- Cr,Vn,Mo and Co are used for imparting good cutting action.</td><td></td><td></td></tr>
<tr><td>e)</td><td>Many high temperature petroleum refining processes are carried out under high partial pressures of hydrogen. Therefore steps for material selection in vessel construction for such service so as to withstand hydrogen which causes deterioration of the material and subsequent failure depends upon identifying some factors like;
• Temperature
• Hydrogen pressure
• Time,
• Composition of materials,
• etc.</td><td>04 marks
01 mark for each</td><td>04</td></tr>
<tr><td>f)</td><td>Difference between Welded and Bolted joints:
<table><tr><td>Parameter</td><td>Welded joint</td><td>Bolted joint</td></tr><tr><td>Labour Cost</td><td>Costly</td><td>Cheap</td></tr><tr><td>Time required</td><td>More</td><td>Less</td></tr><tr><td>Reliability</td><td>More</td><td>Less</td></tr><tr><td>Labour skill</td><td>High</td><td>Less</td></tr><tr><td>Joint efficiency</td><td>High</td><td>Less</td></tr><tr><td>etc.</td><td>……..</td><td>……..</td></tr></table></td><td>04 marks
(any 4 parameters, 01 mark for each)</td><td>04</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Attempt any <u>Two</u> of the following</td><td>8 x 2</td><td>16</td></tr>
<tr><td>a)</td><td>Dilation:
It is defined as the radial growth i.e. growth of the vessel along the radius in a pressure vessel due to internal pressure.</td><td>02 marks</td><td>08</td></tr>
</table>

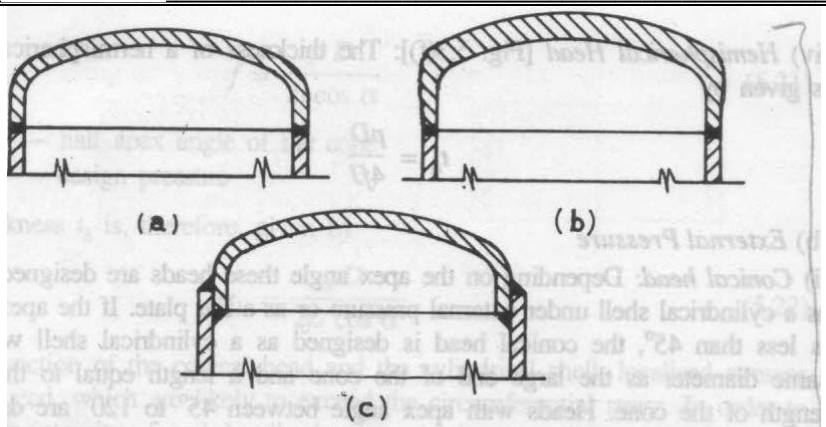
	Dilation of cylindrical vessel: $\delta = Pr^2(2-\mu)/2tE$ Where δ= Dilation or radial growth in mm P= Internal pressure r= Internal radius t= thickness E= modulus of elasticity μ= Poisson's ratio =0.3	**04 marks** **02 marks**	
b)	Data: I. Shell = Cylinder II. Heads = Hemispherical III. ε = 100% (Assume) IV. Inside diameter = 1m, Therefore inside radius, R_i = 0.5m = 500mm V. Design pressure, P = 2N/mm² VI. σult.= 420N/mm² Factor of Safety = 5, Therefore Permissible stress, S = σult. / Factor of Safety = 420 / 5 = 84N/mm² I) Thickness of shell: $t = (P*R_i) / (S\varepsilon - 0.6P)$ = (2*500) / (84*1 – 0.6*2) = (1000) / (84 – 1.2) = (1000) / (82.8) = 12.07mm Consider the chart:	**04 marks**	**08**

VESSEL DIAMETER (m)	MINIMUM SHELL THICKNESS (mm)
Up to 1.0	5
Above 1.0 to 2.0	7
Above 2.0 to 2.5	9
Above 2.5 to 3.0	10
Above 3.0 to 3.5	12

	So shell thickness as per chart is suggested as 5mm But designed value is obtained as 12.07mm Consider the larger value of 12.07mm ≈ 13mm Now, consider the rounded off even value 14mm as thickness of shell for further calculations. 2) Thickness of head: $t = (P*R_i) / 2S\epsilon$ $= (2*500) / 2*84*1$ $= 1000 / 168$ $= 5.95mm$ Consider the rounded off even value 6mm as thickness of hemispherical head.	**04 marks**	
c)	Fatigue concentration: Stress concentrations produced by irregularities are damaging in case of fluctuating stresses. All failures as a result of fatigue are in the areas of high localized stresses. Hence all stresses including localized stresses should be taken into account when designing the pressure vessel. Stress concentration for circular and elliptical holes: $K_t = \sigma_3 / \sigma_{av}$; where $\sigma_{av} = P/t(w-2b)$ $\sigma_1 = P/tw$ $\sigma_3 = \sigma_1(1+ 2b/a)$  Where, b/a = 1 refers to circular opening b/a = 1/2 refers to vertical ellipse with least stress concentration, Kt	**02 marks** **02 marks** **04 marks**	**08**

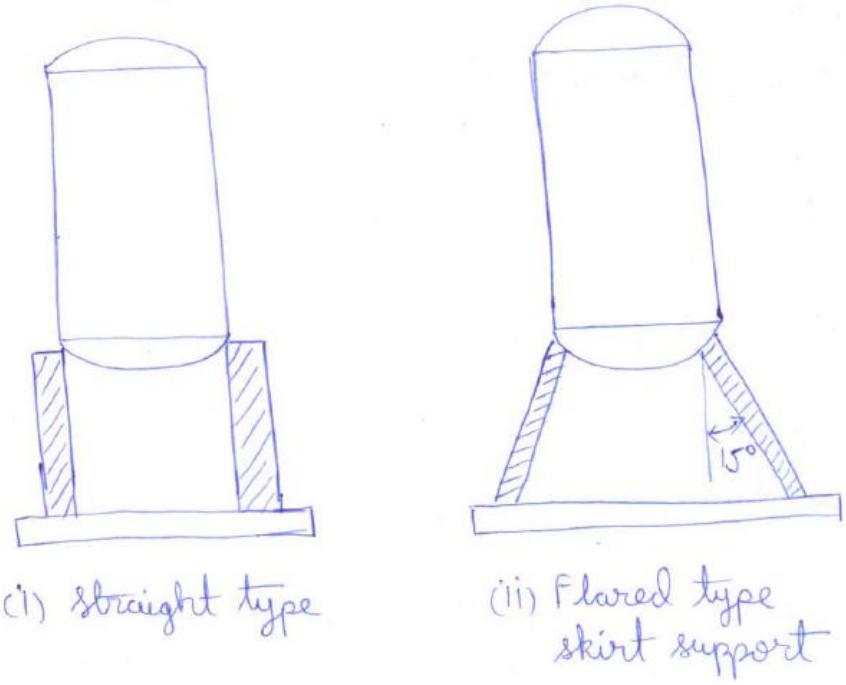
b/a	Kt
1	2.5
2	4.5
3	6.5
1/2	1.5
1/3	2.5
1/4	3.5
1/5	4.5

5	**Attempt any Four of the following**	**4 x 4**	**16**
a)	Some factors while calculating earthquake load are; 1. Identify seismic prone areas with respect to frequency, direction and 2. amplitude of earthquake magnitude 3. Magnitude of damping 4. Allowable stress increase for component materials 5. Live load for seismic load 6. Etc.	**04 marks for any four factors (01 mark for each)**	**04**
b)i)	Dilation efficiency: It is defined as the ratio of dilation factor to the original radial dimension Dilation efficiency = {dilation factor / original radial dimension} x 100	**02 marks**	**04**
ii)	Ligament efficiency: It is the ratio of Area of ligament to the Area of normal section expressed in %age.	**02 marks**	
c)	Weld defects with their causes are: 1. Poor weld shape due to misalignment of parts being welded 2. Cracks in welds due to thermal shrinkage 3. Pin holes on the weld surface 4. Slag inclusion when slag covering a run is not totally removed after every run before the following run. 5. Porosity in the form of voids (cavity) when gases are trapped in the solidifying weld metal 6. Incomplete fusion between the weld and base metal resulting from too little heat input and / or too rapid traverse of the welding torch (gas or electric). 7. Undercutting groove adjacent to the weld left unfilled by weld metal due to incorrect settings / procedure 8. Insufficient penetration of the weld metal in joints arises from too high heat input and / or too slow traverse of the welding torch (gas or electric) 9. Etc.	**04 marks for any 04 defects (01 mark for each defect)**	**04**
d)	Advantages of welded Joints: 1) Welded structures are lighter than riveted structure since other connecting components gussets are not used. 2) Max.efficiency up to 100% 3) Alternation and addition can be easily made. 4) Good strength. 5) Good appearance 6) Any complicated shape can be welded 7) Rigid joint. 8) It is possible to weld any part of structure at any point 9) Leak proof joints are possible 10) Dissimilar material can be joined. 11) It takes less time. 12) Higher thickness can be joined.	**04 marks for any 04 advantages (01 mark for each advantage)**	**04**

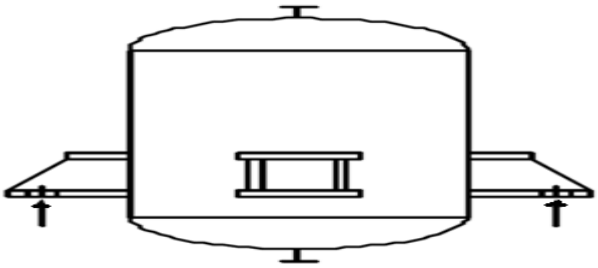
e)	 **Attachment of formed heads to shell: (a) Butt welded, (b) Butt welded with unequal thickness of shell and head, (c) Lap welded** Attachment of Head and Shell : Heads are attached to the shell by a riveted, welded or flanged joint. In the case of riveted or welded joint, either a lap or butt construction is made according to the thickness of the shell and head. Figure shows welded joints.	**03 marks** **01 marks**	**04**
f)	General requirements for selection of materials for pressure vessel construction are: • Design pressure • Design temperature • Corrosion resistance • Types of load • Mechanical properties of material • Fabricability • Availability in the market • Cost/Economy • Quality of future maintenance • Life of product	**04 marks for any 04 points (01 mark each)**	**04**
6	**Attempt any <u>Two</u> of the following**	**8 x 2**	**16**
a)	Pressure Vessel mountings: • Water level Indicator Water level indicator is located in front of boiler in such a position that the level of water can easily be seen by attendant. Two water level indicators are used on all boilers. • Pressure Gauge A pressure gauge is fitted in front of boiler in such a position that the operator can conveniently read it. It reads the pressure of steam in the boiler and is connected to steam space by a siphon tube. Most commonly, the Bourdon pressure gauge is used. • Safety Valve Safety valves are located on the top of the boiler. They guard the boiler against the excessive high pressure of steam inside the drum. If the	**04 marks for any 02 mountings (02 marks for each)**	**08**

	pressure of steam in the boiler drum exceeds the working pressure then the safety valve allows blow-off the excess quantity of steam to atmosphere. Thus the pressure of steam in the drum falls. The escape of steam makes audible noise to warn the boiler attendant. There are four types of safety valve. 1. Dead weight safety valve. 2. Spring loaded safety valve 3. Lever loaded safety valve 4. High steam and low water safety valve. • Fusible Plug It is very important safety device, which protects the fire tube boiler against overheating. It is located just above the furnace in the boiler. It consists of gun metal plug fixed in a gun metal body with fusible molten metal. During the normal boiler operation, the fusible plug is covered by water and its temperature does not rise to its melting state. But when the water level falls too low in the boiler, it uncovers the fusible plug. The furnace gases heat up the plug and fusible metal of plug melts, the inner plug falls down. The water and steam then rush through the hole and extinguish the fire before any major damage occurs to the boiler due to overheating. • Blow-Off Cock The function of blow-off cock is to discharge mud and other sediments deposited in the bottom most part of the water space in the boiler, while boiler is in operation. It can also be used to drain-off boiler water. Hence it is mounted at the lowest part of the boiler. When it is open, water under the pressure rushes out, thus carrying sediments and mud • Feed Check Valve The feed check valve is fitted to the boiler, slightly below the working level in the boiler. It is used to supply high pressure feed water to boiler. It also prevents the returning of feed water from the boiler if feed pump fails to work. • Steam Stop Valve The steam stop valve is located on the highest part of the steam space. It regulates the steam supply to use. The steam stop valve can be operated manually or automatically. Pressure Vessel Accessories: • Economizer An economizer is a heat exchanger, used for heating the feed water before it enters the boiler. The economizer recovers some of waste heat of hot flue gases going to chimney. It helps in improving the boiler efficiency. It is placed in the path of flue gases at the rear end of the boiler just before air pre-heater.	**04 marks for any 02 accessories (02 marks for each)**	

	• Super heater It is a heat exchanger in which heat of combustion products is used to dry the wet steam, pressure remains constant, its volume and temperature increase. Basically, a super heater consists of a set of small diameter U tubes in which steam flows and takes up the heat from hot flue gases. • Air Pre-heater The function of an air pre-heater is similar to that of an economizer. It recovers some portion of the waste heat of hot flue gases going to chimney, and transfers same to the fresh air before it enters the combustion chamber. Due to preheating of air, the furnace temperature increases. It results in rapid combustion of fuel with less soot, smoke and ash. The high furnace temperature can permit low grade fuel with less atmospheric pollution. The air pre-heater is placed between economizer and chimney. • Feed Water Pump It is used to feed the water at a high pressure against the high pressure of steam already existing inside the boiler. • Steam Injector A steam injector lifts and forces the feed water into the boiler. It is usually used for vertical and locomotive boilers and can be accommodated in small space. It is less costly. It does not have any moving parts thus operation is salient.		
b)	Following are the design consideration for thermal stress. • Local flexibility capable of absorbing expansion joints or a flexible structural member • Change in design is desirable to solve thermal stress problems. • Shape of weldment (weld) or casting that may cause a steep temperature gradient under operating condition should be avoided by proper contouring of the part. • A favourable contour should be used i.e. Surface of revolution in preference to a flat surface. • Sources of stress concentration, abrupt changes in cross section, holes or mass accumulation should be minimsed. • Thermal expansion can be better handled by dividing large parts. • Selection of proper materials or combination of material. • Use of insulation.	**08 marks for 08 points (01 mark for each point)**	**08**

c)i	 Support skirt: Tall vertical vessels are supported by cylindrical shell called as skirt. The skirt is a suitable supporting structure for tall vessels which are subjected to wind load, seismic load and other load. The skirt is welded to the bottom dish end from the outside of the shell. A bearing plate/ base plate/ support plate is attached to the bottom of the skirt. The plate is made to rest on a concrete foundation and is securely anchored to foundation by means of anchor bolts embedded in concrete to prevent overturning due to wind load or earthquake load. The commonly used materials for skirt supports are carbon steels. 1) Straight type skirt support is used for tall vessels. The centre line of cylindrical skirt and shell are coincident. This type is more difficult to fabricate and is used mainly for high external loads, high design temperatures or cyclic operating temperatures. A good fit between the outside diameter of the shell and inside diameter of skirt is a must. 2) Flared type skirt support is used for very high columns with high external moments. The angle of skirt is maximum 15^{o}.	**1/2 mark** **1/2 mark** **1/2 mark** **1/2 mark**	**08**

ii



1/2 mark

Support lug:

Brackets are fabricated from plates and are attached to the vessel wall. They are made to rest on small columns or beams of structure depending on the elevation required. They can be easily leveled. Due to the eccentricity of these supports, compressive, tensile and shear stresses are induced in the vessel wall. Bracket supports are suitable for vessels with thick walls.

1/2 mark

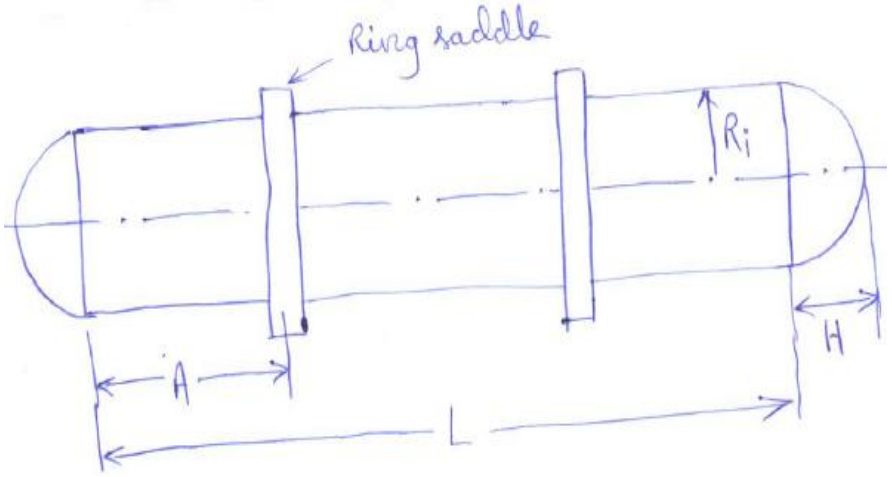
Diameter of vessel	Number of brackets
Upto 0.6m	2
Upto 3.0m	4
Upto 5.0m	6
Above 5.0m	8

1/2 mark

The main loads on the bracket supports are the dead weight of the vessel with its content and the wind load. The wind load tends to overturn the vessel when it is empty. Use of bracket or lug support is limited to vertical pressure vessels with diameter Ø ranging from 1’ to 10’ (0.3m to 3.0m) and a moderate height to diameter ratio as h / d = 5 / 2.

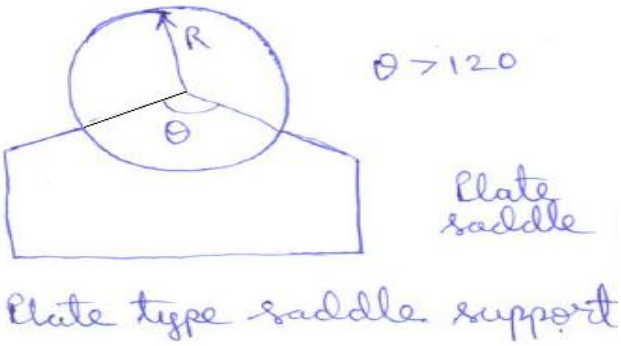
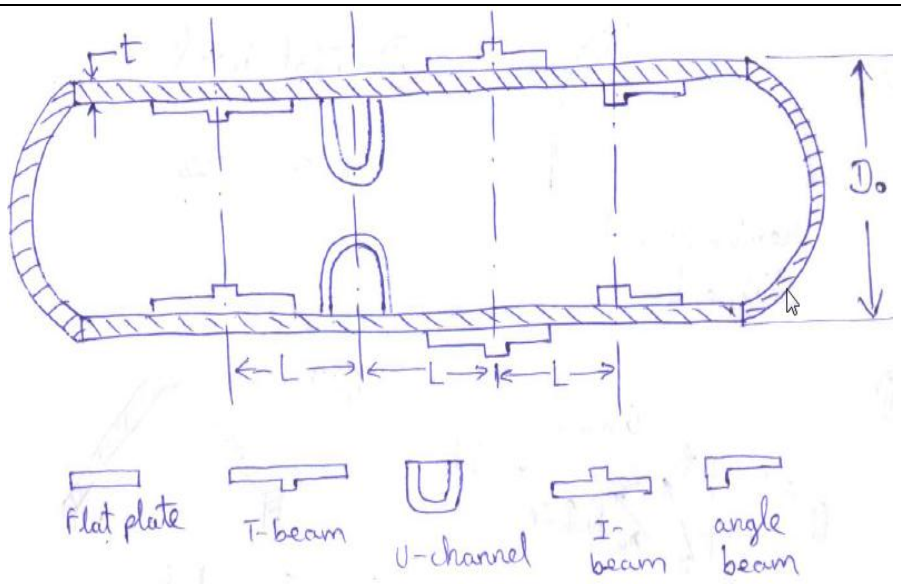
1/2 mark

iii



1/2 mark

Saddle support

	 Saddles: Horizontal cylindrical vessels are supported on saddles. These are placed at minimum two positions. The shell of a vessel is strengthened by stiffeners and supported by using saddle supports. These are used for large thin walled vessels or vessels under vacuum. Supports in the form of rings are preferable for vessels in which supports at more than two positions are essential. Types are; 1) Plate type saddle support: In this included angle θ should be greater than 120^{o}. 2) Ring type saddle support: In this support, distance A = (0.4 to 0.5) times Ri or A < 0.2L Commonly used material for saddle is steel. The design load for saddle supports are; Operating weight + wind load + earthquake load + friction between saddle and foundation + test load	**1/2 mark** **1/2 mark** **1/2 mark**	
iv	 Stiffners: Considerable saving in weight and material can be made by use of stiffening rings (reinforcing rings). Stiffening rings are attached on the inside or outside surface of the shell.	**01 mark** **01 mark**	

	These rings extend over the whole circumference and serve the purpose of end supports. T- beams, flat plate rings, I-beam, U-channel, angles, etc. bolted/ riveted/welded to the shell can be used as stiffening rings.		