UNIT-I UNIFORM FLOW

Part A

1. **Define Open-Channel flow.[April/May 2010]**

The flow of liquid with a free surface (i.e., surface exposed to atmosphere) through any passage is known as open channel flow. The liquid flowing through any closed passage without touching the top can also treated as open channels.

Ex:i) Flow in natural waterfall. River and stream; ii) Flow in artificial or man-made channels such as irrigation channels and flumes. iii) Closed conduit or pipe carrying liquid partially. (sewers that carry domestic waste water).

2. **Compute the hydraulic mean depth of a small channel 1m wide, 0.5m deep with water flowing at 2m/s. [April/May 2010]**

Hydraulic depth in m, $D = \frac{Cross\ sectional\ area\ of\ flow}{Wetted Perimeter} = \frac{0.5x1}{1+(2x0.5)} = 0.25m$

3. **Write down the Chezy's formula for determining velocity of flow in an open channel. [April/May 2010]**

$V = C\sqrt{RS}$ **; Where** C-Chezy's constant, S-Slope of the channel bed

$R = \frac{A}{P}$ is the hydraulic radius

4. **Show that maximization of discharge requires minimization of the wetted perimeter of the channel for a given area of flow. [April/May 2010]**

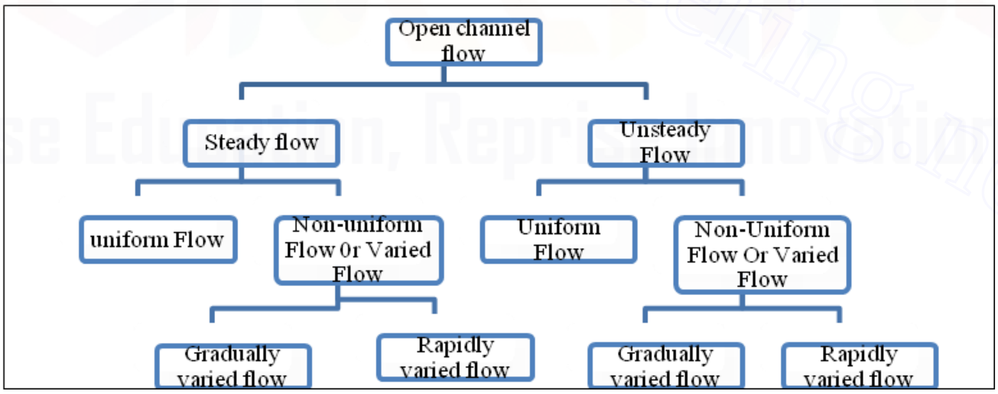
For a given channel slope, roughness coefficient and area of flow, the maximum discharge of channel are obtained when the wetted perimeter is minimum.

For wetted perimeter (P) to be minimum, $\frac{dp}{dy} = 0$. If the second derivative of P is positive, the condition of minimum P is obtained.

5. **What are the different types of flow in open channel? [MAY/JUNE2012, MAY/JUNE2016]**

The flow in open channel is classified into the following types:

a. Steady and unsteady flow
b. Uniform and non- uniform flow
c. Laminar and turbulent flow
d. Subcritical, critical and supercritical flow.



6. **Define specific energy and what is the condition for obtaining only one depth for a given specific energy? [MAY/JUNE 2012,MAY/JUNE 2016, MAY/JUNE 2017]**

The total energy of flow per unit weight of the liquid, $E = Z + y + \frac{V^2}{2g}$.

Where Z is the elevation of the channel bottom above the horizontal datum, y depth of flow and V the average velocity of flow. If the channel bed is considered as datum line, Z=0, then the energy equation is called specific energy. Specific energy, $E = y + \frac{V^2}{2g}$

From specific energy curve, corresponding to specific energy minimum (E_{min}), there is only one depth of flow which is called critical depth.

7. **What are the conditions for the most economical triangular channel section? [MAY/JUNE2012]**

The triangular channel is most economical when the side slopes are 1V: 1H or the side slope at 45^o with the vertical. The Corresponding hydraulic radius R

$$R = \frac{A}{P} = \frac{y^2 \tan\theta}{2y\sqrt{1+\tan^2\theta}} = \frac{y^2 \tan 45^o}{2y\sqrt{1+\tan^2 45^o}} = \frac{y}{2\sqrt{2}}$$

8. **What is a prismatic channel?[MAY/JUNE 2013]**

Geometric dimensions of the channel, such as cross section and bottom slope are constant throughout the length of the channel is called as a prismatic channel. Eg. Most of the artificial channels of circular, rectangular, trapezoidal and triangular cross section are called prismatic channels.

9. **What are the factors affecting Manning's roughness coefficient. [MAY/JUNE 2013]**

The following factors affecting Manning's roughness coefficient are:

1. Surface roughness 2. Vegetation growth 3. Channel irregularities 4. Silting and scouring5. Stage(water surface elevation) and discharge; 6. Transport of suspended and bed material.

10. **On what condition most economical trapezoidal channel section is derived?[MAY/JUNE 2013]**

For the most economical section of a trapezoidal channel is

i) Sloping side of cross section is equal to half of the top width.

ii) Angle of channel sides make with horizontal is 60^0.

iii) Hydraulic radius is equal to half the depth of water.

11. **Write the empirical relation for Manning's formula with expansion. [MAY/JUNE 2014]**

Empirical Formula is based on the analysis of various discharge data. This formula is widely used. $V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$; $R = \frac{WettedArea}{WettedPerimeter} = \frac{A}{P}$

Where V=mean velocity of flow in m/s; n=a roughness coefficient or Manning's constant or rugosity coefficient R=hydraulic mean radius of the channel cross-section in m.

12. **What is meant by best section?[MAY/JUNE 2014]**

In the open channel flow, a section with minimum wetted perimeter(or maximum hydraulic radius) is known as best section. Best section of s channel gives the maximum discharge with a constant cross section.

13. **Define open channel flow. [MAY/JUNE 2014, NOVEMBER/DECEMBER 2016]**

The flow of liquid with a free surface (i.e., surface exposed to atmosphere) through any passage is known as open channel flow. The liquid flowing through any closed passage without touching the top can also treated as open channels.

Ex:i) Flow in natural waterfall. River and stream; ii) Flow in artificial or man-made channels such as irrigation channels and flumes.iii) Closed conduit or pipe carrying liquid partially (sewers that carry domestic waste water).

14. **Define and distinguish between steady flow and unsteady flow.[MAY/JUNE 2015]**

In steady flow, various characteristics of flowing fluids such as velocity, pressure, density, temperature etc. at a point do not change with time. In other words, a steady flow may be defined as that in which the various characteristics are independent of time.

Mathematically, $\left(\frac{\partial u}{\partial t}\right) = 0; \left(\frac{\partial p}{\partial t}\right) = 0; \left(\frac{\partial \rho}{\partial t}\right) = 0$.

In Unsteady flow, the various characteristics of flowing fluid such as velocity, pressure, density etc. at a point change with respect to time. Mathematically, $\left(\frac{\partial u}{\partial t}\right) \neq 0; \left(\frac{\partial p}{\partial t}\right) \neq 0; \left(\frac{\partial \rho}{\partial t}\right) \neq 0$.

15. **What is meant by most economical section? [MAY/JUNE 2015]**

The most economical cross-section of a channel is one which offers least resistance to flow and hence passes maximum discharge for a given slope, area and roughness. From continuity equation, it is clear that the discharge is maximum when the velocity is maximum; the cross-sectional area of channel remains constant. The velocity is maximum when the wetted perimeter P is minimum as the resistance decreases to flow.

16. **Write the Bazin's formula for the discharge in the canal. [April / May 2017]**

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{m}}}$$

Where, K= Bazin's constant and depends upon the roughness of the surface of channel and m= Hydraulic mean depth or hydraulic radius.

17. Differentiate open channel flow from pipe flow.[NOV/DEC 2009]

Pipe Flow	Open Channel Flow
In pipe flow, the flow takes place by hydraulic pressure	Open channel flow takes place by gravity force.
Pipes are generally circular in cross section	They can have any shape such as; triangular, rectangular, trapezoidal and circular
Hydraulic gradient line does not coincides with water surface	HGL coincides with the water surface
Velocity distribution is symmetrical about the pipe axis.	The shape of the velocity profile is dependent on the channel roughness
Flow cross section is fixed.	Flo cross section depends on depth of flow
The maximum velocity occurs at centre of the pipe.	Maximum velocity occurs at a little distance below the water surface

18. State the condition for maximum velocity and maximum discharge in circular channel. [NOV/DEC 2009]

a. Condition for maximum velocity of circular section
   (i) Depth of flow is 0.81 times the diameter of the circular channel.
   (ii) Hydraulic radius is equal to 0.3 times the diameter of channel.
   (iii) For angle subtended by water surface from the centre, 2 θ= $257^0 30'$.

b. Condition for maximum discharge of a circular section.
   (i) Depth of flow is 0.95 times the diameter of the circular channel.
   (ii) Hydraulic radius is equal to 0.286 times the diameter of channel.
   (iii) For the angle subtended by water surface from the centre, 2 θ= 308^0.

19. What is equivalent roughness or composite roughness of an open channel? [NOV/DEC 2011]

Equivalent roughness or composite roughness factor is used for composite channel flow calculations. It is denoted by 'n_e'. $n_e = \left[\frac{\sum_{i=1}^{N}\left(P_i n_i^2\right)}{\sum_{i=1}^{N}\left(P_i\right)}\right]^{\frac{1}{2}}$

Where P_i-force resisting the flow for i^{th} segment
n_i- roughness coefficient for i^{th} segment
i-segment number

20. A river with a lined banks has a Manning's n=0.014 and Chezy's C=55, what is its hydraulic radius? [NOV/DEC 2011]

$C = \frac{1}{n} X R^{\frac{1}{6}}$; Where R-Hydraulic radius in m

$$55 = \frac{1}{0.014} X\, R^{\frac{1}{6}} \Rightarrow R^{\frac{1}{6}} = 0.014X55 = 0.77 \Rightarrow R = 0.208m$$

21. Define uniform flow in channels? [NOV/DEC 2012,2016, NOV/DEC 2018]

If the depth of flow, slope of the bed of channel and cross section remain constant with respect to distance, it is called uniform flow.Ex:i)open channel flow with constant depth of water; ii)Flow through uniform diameter pipes.

$$\left(\frac{\partial y}{\partial s}\right) = 0; \left(\frac{\partial V}{\partial s}\right) = 0$$

22. What are non-erodible channels? [NOV/DEC 2012]

Channels which are constructed from materials such as concrete, masonry and metals can withstand erosion under non-erodible channels.

23. Define hydraulic mean depth?[NOV/DEC 2012]

Hydraulic Mean Radius,

$$R = \frac{Wetted area}{Wetted perimeter} = \frac{A}{P}$$

24. In an open channel of rectangular section if the minimum specific energy is 6m, what is its critical depth?

$$E_{\min} = \frac{3}{2} y_c$$

Critical depth, $y_c = \frac{2}{3} E_{\min} = \frac{2}{3} X6 = 4m$

25. A rectangular channel carries a flow of 8m^3/s /m and discharge of 15m^3/s, what is the critical depth and critical velocity?(NOV/DEC 2017)

Critical depth, $y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$;

Where q=Discharge per 'm' width= $\frac{Q}{width} = \frac{Q}{b} = 5 \, m^3/s/m$

Critical depth, $y_c = \left(\frac{(5)^2}{9.81}\right)^{\frac{1}{3}}$ =0.74m

Critical Velocity, $V = \sqrt{gy}$

$= 9.81 * 0.74$

$= 7.25$cumec

26. Give a brief note on Sub-critical, Critical, Super critical flow.[APR/MAY 2018]

Sub critical flow: The flow in open channel is said to be sub-critical if the Froude number is less than 1.

Critical Flow: The flow in open channel is said to be critical if the Froude number is 1.

Super critical flow: The flow in open channel is said to be super critical if the Froude number is greater than 1.

Part-B

1. (i) Define specific energy. How would you express the specific energy for a wide rectangular channel with depth of flow '*d*' and velocity of flow '*V* '? Draw the typical specific energy diagram and explain its features.
   (ii) Calculate the specific energy, critical depth and velocity for the flow of 10 m^3/s in a cement lined rectangular channel 2.5 m wide with 2 m depth of water. Is the given flow subcritical or supercritical? **[APRIL/MAY 2010]**
2. (i) Define Froude number F_r. Describe the flow for $F_r=1$, $F_r>1$ and $F_r<1$. Represent a discharge versus depth curve for a constant specific energy and explain its features.
   (ii) A trapezoidal channel has a bottom width of 6.1 m and side slopes of 2 H : 1 V. When the depth of flow is 1.07 m, the flow is 10.47 m^3/s? What is the specific energy of flow? Is the flow tranquil or rapid? **[APRIL/MAY 2010]**
3. Derive the expressions for the most economical depths of flow of water in terms of the diameter of the channel of circular cross-section:
   (i) For maximum velocity and (ii) For maximum discharge. **[APRIL/MAY 2010]**
4. (i) How do you determine velocity of flow in open channels?
   (ii) The bed width of a trapezoidal channel section is 40m and the side slope is 2 horizontal to 1 vertical. The discharge in the canal is 60 cumecs. The Manning's 'n' is 0.015 and the bed slope is 1 in 5000. Determine the normal depth.**[APRIL/MAY 2012]**
5. (i) Explain the salient features of Specific Energy curve.[**MAY/JUNE 2012]**
   (ii) Determine the critical depth for a specific energy of 1.5 m in the following channels.
      a) Rectangular Channel
      b) Triangular Channel
      c) Trapezoidal Channel
6. Water flows at rate of 20 cumecs in a rectangular channel 14 m wide at a velocity of 1.8m/s. Determine the specific energy of the flowing water, critical velocity and minimum specific energy corresponding to this discharge, the Froude number and state whether the flow is subcritical or supercritical. **[MAY/JUNE 2013]**

7. A trapezoidal channel with side slopes 1:1 has to be designed to convey $15m^3$/sec at a velocity of 3 m/sec so that the amount of concrete lining for the bed and sides is the minimum. Calculate the area of lining requires for one metre length of channel. **[MAY/JUNE 2013]**
8. (i) How the stream discharge is measured by chemical method? Explain.
(ii) Derive Chezy's formula to determine the velocity of flow in open channel. **[MAY/JUNE 2013, NOV/DEC 2017, APR/MAY 2018]**
9. (i) Calculate the specific energy of 12 m^3/sec of water flowing with a velocity of 1.5 m/s in a rectangular channel 7.5 m wide. Find the depth of water in the channel when the specific energy would be minimum. What would be the value of critical velocity as well as minimum specific energy?
(ii)Derive an expression for critical depth and critical velocity. **[APRIL/MAY 2014, NOVEMBER/DECEMBER 2016]**
10. (i) For a rectangular channel with bottom width 40 m and side slopes 2H:1V, Manning's N is 0.015 and bottom slope is 0.0002. If it carries 60m3/s discharge, determine the normal depth.
(ii) Derive Chezy's formula. **[APRIL/MAY 2014]**
11. A most economical trapezoidal section is required to give a maximum discharge of 20 m^3/s of water. The slope of the channel bottom is 1 in 1500. Taking C=70, in Chezy's equation, determine the dimensions of the channel. **[MAY/JUNE 2015]**
12. (i) Derive the relationship between flow depth and breadth of a rectangular channel, to be an economical section.
(ii) A rectangular channel which is laid on a bottom slope of 1 in 160 is to carry 20 m^3/s of water. Determine the width of the channel when the flow is in critical condition. Take Manning's constant n=0.014. **[MAY/JUNE 2015]**
13. (i) The Specific energy for a 3m wide channel is 8Nm/N. What is the maximum possible discharge in the channel?
(ii)Show that in a rectangular channel, maximum discharge occurs when the flow is critical for a given value of specific energy. [**MAY/JUNE 2016]**
14. (i)Show that the hydraulic radius is half the flow depth for the most economical trapezoidal channel section.
(ii)Determine the most economical rectangular channel carrying water at the rate of 0.6cumecs. the bed slope of the channel is 1 in 2000. Assume Chezy's constant C=50**[MAY/JUNE 2016]**
15. Derive the geometrical properties of a most economical triangular channel section**. [MAY/JUNE 2017]**
16. Show that the friction factor of the Darcy's Weisbach equation and the Manning's roughness factor 'n' are interrelated by $f= 78.5n^2/(R^{1/3})$
17. Prove that half of the top width of a most economical trapezoidal section is equal to the length of the one of the sides slopes and derive the hydraulicdepth as half of the depth of the flow**(NOV/DEC 2017)**

PART C

1. (i)A V-shaped open channel of included angle 90° conveys a discharge of 0.05 m^3/s when the depth of flow at the center is 0.225 m. Assuming that C = 50 $m^{1/2}$/s in the Chezy's equation, calculate the slope of the channel.
(ii) Calculate the dimensions of the rectangular cross-section of an open channel which requires minimum area to convey 10 m^3/s. The slope being 1 in 1500. Take the Manning's '*n*' as 0.013. **[APRIL/MAY 2010, NOVEMBER/DECEMBER 2016].**
2. (i)Show that the hydraulic radius is half the flow depth for the most economical trapezoidal channel section. (ii)Determine the most economical rectangular channel carrying water at the rate of 0.6cumecs. the bed slope of the channel is 1 in 2000. Assume Chezy's constant C=50**[MAY/JUNE 2016, APRIL/MAY 2012]**
3. (i)How the flows are classified under specific energy concepts?
(ii)A 8m wide channel conveys 15cumecs of water at a depth of 1.2m. Determine Specific energy of the flowing water, critical depth, critical velocity, min specific energy, Froude Number and state whether the flow is sub-critical or super critical**[MAY/JUNE 2012, MAY/JUNE 2016]**
4. A trapezoidal channel having a cross sectional area A_1, wetted perimeter P_1, Manning's co-efficient 'n' and laid to a slope S, base width b, carries a certain discharge Q_1 at a depth of flow equal to 'd'. To increase the discharge, the base width of the channel is widened by 'x', Keeping all other parameters viz., S, d, side slope and n are same. Q_2 is the new discharge in the channel. Prove that, **[MAY/JUNE 2017]**

$$\mathbf{(Q_2 / Q_1)^3 (1+ (x/P_1))^2 = (1 + (xd/A_1))^5}$$

5. (i) A 3m wide rectangular channel conveys $12m^3$/s of water at a depth of 2 m. Calculate
   1. Specific energy of flowing fluid

2. Critical depth, critical velocity and the minimum specific energy
3. Froude number and state whether flow is subcritical or supercritical.

(ii) What do you understand by critical depth of an open channel when the flow in it is not uniform? **[APRIL/MAY 2014, NOVEMBER/DECEMBER 2016]**

6. Prove that half of the lop width of a most economical section is equal to the length of the one of the side slopes and derive the hydraulic mean depth as half of the depth of the flow(**NOV/DEC 2017)**
7. A rectangular channel carries a water flow of 20 m3/s and has n=0.014 and bed width as 6.5 m. Find the following: (i)Critical depth (ii) Minimim specific energy (iii) Depth of flow for specific energy of 3.5m (iv) What is the type of flow if the depths of flow are 2 m and1.5 m?

UNIT-II GRADUALLY VARIED FLOW

Part A

1. **Distinguish between normal depth and critical depth.** [MAY/JUNE 2012]

Normal depth (y_o): For a given channel geometry, slope, roughness and a specified value of discharge, a unique value of depth occurs in a steady, uniform flow, it is called as normal depth and denoted by the symbol 'y_o'. The normal depth is used to design artificial channels in a steady and uniform flow is computed from Manning's equation.

Critical Depth(y_c): Depth of flow of water at which the specific energy, E is minimum is called as critical depth (y_c). Depth (y_c) corresponding to minimum specific energy is called critical depth.

2. **Write down the dynamic equation of Gradually Varied flow.** [MAY/JUNE 2012,2015]

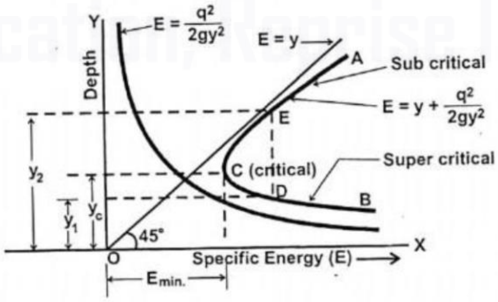
The dynamic equation of gradually varied flow is given by

Slope of free water surface, $\frac{dy}{dx} = \frac{S - S_e}{1 - \frac{V^2}{gD}} = \frac{S - S_e}{1 - F^2}$

Where S_e-slope of energy line
S-Bed slope
V-Velocity of flow
D-Depth of flow

3. **State the condition for critical and super-critical flow. [MAY/JUNE 2014, APR/MAY 2018]**

The flow at critical depth is called critical flow and the velocity of flow is known as critical velocity. When the depth is less than the critical depth, the velocity of flow is greater than the critical velocity, and hence the flow is called super-critical or rapid flow.



4. **State the assumptions made in the derivation of dynamic equation of gradually varied flow. [MAY/JUNE2015, NOV/DEC 2009]**

The following assumptions are made for analyzing the gradually varied flow:

a. The flow is steady.
b. The pressure distribution over the channel section is hydrostatic, i.e., streamlines are practically straight and parallel.
c. The head loss is same as for uniform flow.
d. The channel slope is small, so that the depth measured vertically is the same as depth measured normal to the channel bottom.
e. A channel is prismatic.
f. Kinetic energy correction factor is very close to unity.
g. Roughness coefficient is constant along the channel length.

h. The formulae, such as Chezy's formula, Manning's formula which are applicable, to the uniform flow are also applicable for the gradually varied flow for determining slope of energy line.

5. Distinguish between draw down and back water curves. [NOV/DEC 2007,NOV/DEC 2008,MAY/JUNE2010, MAY/JUNE2016]

When the depth of flow decreases along the flow direction $\frac{dy}{dx}$ becomes negative and the surface profile is called draw down curve. When the depth of flow increases along the flow direction $\frac{dy}{dx}$ becomes positive (upward slope) and the water surface profile is called backwater down curve.

6. Differentiate between normal depth and alternate depth. [NOV /DEC 2016].

Alternate depth in a specific energy curve, if a vertical line representing a given specific energy is drawn, it intersects the specific energy curve at two points. Normal Depth: the depth at which the uniform flow occurs is known as normal depth. The energy line slope is equal to the bottom slope and $\frac{dy}{dx} = 0$.

7. Differentiate Uniform and Non-uniform flow. [MAY/JUNE 2017, APR/MAY 2018]

Uniform Flow	Non-Uniform flow
If for a given length of the channel, the velocity of flow, depth of flow, slope of the channel and cross-section remain constant, the flow is said to be uniform flow.	If for the given length of the channel, the velocity of flow, depth of flow etc., do not remain constant the flow is said to be non-uniform flow.
Mathematically expressed as, $\left(\frac{\partial y}{\partial s}\right) = 0; \left(\frac{\partial V}{\partial s}\right) = 0$	Mathematically expressed as, $\left(\frac{\partial y}{\partial s}\right) \neq 0; \left(\frac{\partial V}{\partial s}\right) \neq 0$
Uniform flow is possible only in prismatic channels.	Non uniform flow can be Rapidly varied flow (R.V.F) or Gradually varied flow (G.V.F.)

8. Write down the characteristics of GVF. [MAY/JUNE 2017]

1. The depth variation along the channel is gradual.
2. It occurs over a long distance.

9. Classify the channel bottom slopes. [MAY/JUNE 2015]

Based on slope of channel bed(S), normal depth of water (y_0) and critical depth (y_c), the channel are classifies into five categories. If the flow in the channel is uniform, the channel is said to have a normal slope denoted by S_n.

a. Mild Slope(M)
b. Critical slope (C)
c. Steep slope(S)
d. Adverse slope(A)
e. Horizontal slope(H)

10. Define gradually varied flow and rapidly varied flow in open channel [NOV/DEC 2008,2007].

When the depth variation along the channel is gradual and occurs over long distance, it is said to be GVF. Example: Back Water in a dam.

When the depth variation along the channel is almost sudden and occurs over short length, it is said to be RVF Example: Hydraulic Jump

11. Write the expression to determine the length of the backwater curve. [NOV/DEC 09]

The length of backwater curve, $L = \frac{E_2 - E_1}{S - S_e}$

Where E_2, E_1= Energy head; Se=Slope of energy line; S=Slope of bed

12. What are the flow profiles possible in mild sloped channels?[NOV/DEC 2006]

a. Flow behind an overflow weir
b. Flow over a free over fall
c. Flow downstream of a sluice gate.

13. Write about the zones above the channel bottom.

The space above the channel bottom is divided into three zones

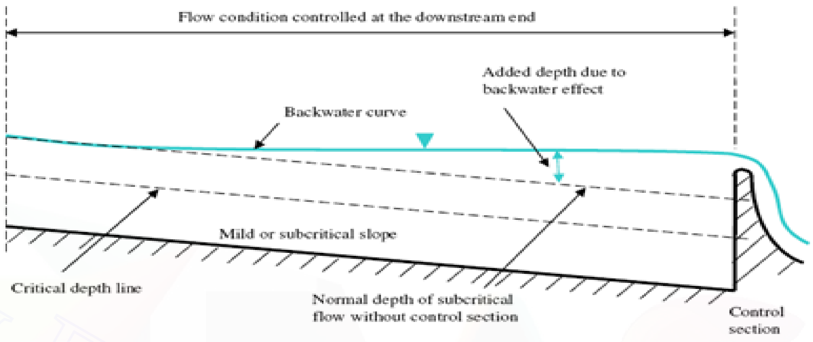
a. Region which lies above the normal depth line and critical depth line.
b. Region which lies between the normal depth line and critical depth line.
c. Region which lies below the normal depth line and critical depth line but above the channel bottom.

14. Define the Afflux.(NOV/DEC 2008, NOV/DEC 2017)

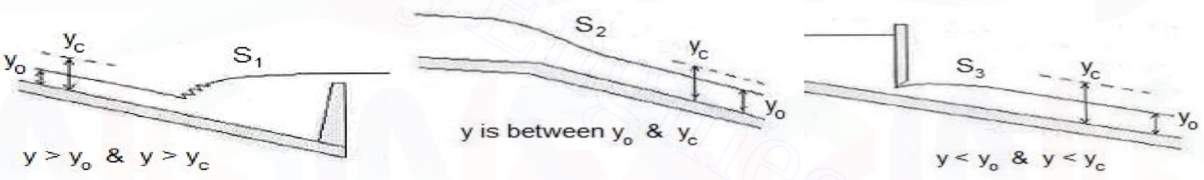
Afflux is defined as the maximum increase in the water level due to obstruction in the path of flow of water.

15. What is backwater curve in gradually varied flow profile and give practical example for getting this type of profile. [NOV/DEC 2006]

When the depth of flow increases along the flow direction $\frac{dy}{dx}$ becomes positive (upward slope) and the water surface profile is called backwater down curve. Due to obstruction (dam), the water level rises and it has maximum depth of water near the dam as shown figure, is an example for backwater flow.



16. Sketch S type surface profiles.



17. Define spatially varied flow (SVF).

Flow varies with longitudinal distance called spatially varied flow. In steady varied flow, no flow is externally added to or taken out of the channel system and the discharge is constant at all sections. However, if flow is externally added to or taken out of the channel system it is known as SVF. Example: Lateral Weir, Lateral channel spillways, Channel with permeable boundaries.

18. What are the methods used to determine the length of surface profile?

The length of surface profile is determined by

a. Graphical integration method
b. Direct step method
c. Standard step method

19. Define varied flow. Explain its classification.

Flow properties such as depth of flow, area of cross section and velocity of flow vary with respect to distance called non uniform flow. It is also called varied floe. Varied flow is broadly classified in to two types:

i) Rapidly Varied Flow
ii) Gradually Varied Flow

20. Define control section and how it affects the flow depth.

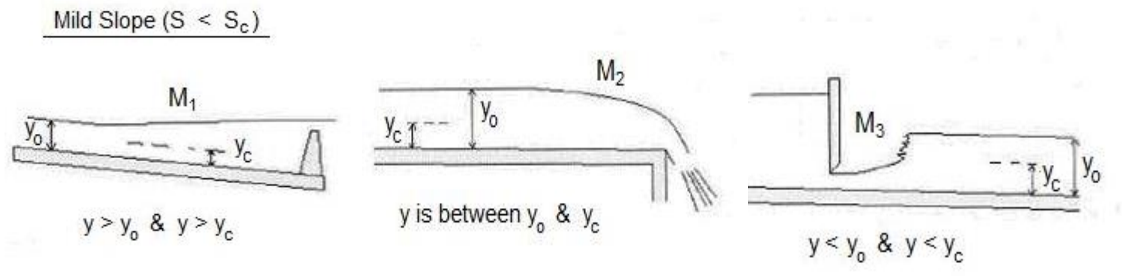
A section were a definite relation between the depth of flow and discharge exist is known as control section. For critical flow, there is a definite discharge relationship and hence a critical depth section is a control section.

It is the suitable site for measuring flow in open channels. Subcritical flows are affected by changes in downstream conditions. The control section for such flows is therefore located downstream, on the other hand upstream conditions affect super-critical flow and hence the control section for such flows are located upstream. A section where channel slope changes from Mild to Steep is also a control section.

21. **What are the types of spatially varied flow?**
Spatially varied flow can be steady or unsteady.
   i. **Steady SVF-** the flow discharge is steady but it varies along the channel length. Example: Flow over a bottom rack.
   ii. **Unsteady SVF-** the production of surface runoff due to rainfall is known as overland flows, it is a typical example for unsteady SVF.

22. **What is normal slope of an open channel?**
If the flow in the channel is uniform, the channel is said to have normal slope.

23. **Sketch the different zones of water surface profiles in a critical and mild sloped channels.[NOV/DEC 2017]**



Critical slope

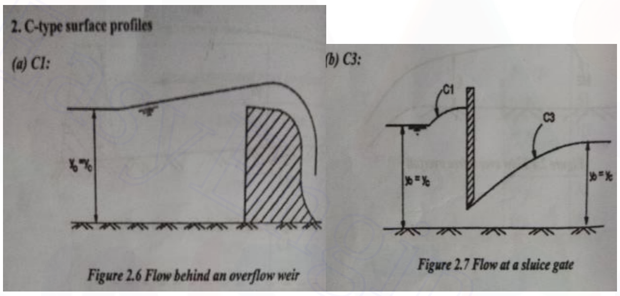


Figure 2.6 Flow behind an overflow weir
Figure 2.7 Flow at a sluice gate

24. **Show that maximization of discharge requires minimization of the wetted perimeter of the channel for a given area of flow. [April/May 2010]**
For a given slope channel slope, roughness coefficient and area of flow, the maximum discharge of channel is obtained when the wetted perimeter is minimum.

For wetted perimeter (P) to be minimum, $\frac{dP}{dy}=0$

If second derivative of P is positive, the condition of minimum P is obtained.

25. **How spatially varied flow is classified based on discharge?**
Spatially varied flow can be classified into two types.
   i. Discharge increases with distance-Lateral flow
   ii. Discharge decreases with distance-Lateral outflow

Part B

1. (i) In a given channel, $Y_0$and $Y_c$are two fixed depths if Q ,n and $S_0$are fixed. Also, there are three possible relations between Y_0andY_c. Further, there are two cases where Y_0does not exist. Based onthese, how the channels are classified?
(ii) A river 100 m wide and 3 m deep has an average bed slope of 0.0005. Estimate the length of the GVF profile produced by a low weir which raises the water surface just upstream of it by 1.5 m. Assume n = 0.035. Use direct step method with three steps **[APRIL/MAY 2010,MAY/JUNE 2016]**
2. (i) What are the assumptions made in the analysis of gradually varied flow?
(ii) The bed width of a rectangular channel is 24 m and the depth of flow is 6 m. The discharge in the channel is 86 cumecs. The bed slope of the channel is 1 in 4000. Assume Chezy's constant C=60. Determine the slope of the free water surface **[NOV/DEC 2011]**
3. (i)Explain how the profiles are classified.
(ii) Explain the development of M, S and H profiles with neat sketches. **[MAY/JUNE 2013]**

4. Discuss the different surface profiles for the various bottom slope conditions of channels. **[MAY/JUNE 2015]**
5. A rectangular flume 2m wide discharge at the rate of 2 m^2/s. The bed slope of the flume is 1 is 2500. At a certain section the depth of flow is 1m. Calculate the distance of the section downstream where the depth of flow is 0.9m. Solve by single step method. Assume n=0.014. **[MAY/JUNE 2015,MAY/JUNE 2016,NOV/DEC 2017]**
6. A river 100 m wide and 3 m deep has an average bed slope of 0.0005. Estimate the length of the GVF profile produced by a low weir which raises the water surface just upstream of it by 1.5 m. Assume n = 0.035. Use direct step method with three steps **[APRIL/MAY 2010,MAY/JUNE 2016]**
7. State and discuss the assumptions made in the derivation of the dynamic equation for gradually varied flow. Starting from first principles, derive equations for the slope of the water surface in gradually varied flow with respect to i) Channel bed and ii) horizontal. **[MAY/JUNE 2017,APR/MAY 2018]**
8. Explain the features of water surface flow profile classifications. **[MAY/JUNE 2017]**
9. Derive the dynamic equation of gradually varied flow. Write the assumptions made in it. **[NOV/DEC 2012,2017]**
10. (i) Explain the step method of integrating the varied flow equation for the channel section.
    (ii) What are the characteristics of surface profiles in horizontal channels? **[NOV/DEC 2007]**
11. (i)Briefly explain the direct step method and standard step method to determine the gradually varied flow profiles. **[APR/MAY 2018]**
    (ii) Explain the development of M, S and H profiles with neat sketches. **[NOV/DEC 2009]**
12. (i) What are the assumptions made in the analysis of gradually varied flow?
    (ii) The bed width of a rectangular channel is 24 m and the depth of flow is 6 m. The discharge in the channel is 86 cumecs. The bed slope of the channel is 1 in 4000. Assume Chezy's constant C=60. Determine the slope of the free water surface **[NOV/DEC 2011]**
13. A rectangular channel 10m wide carries a discharge of 30 m^3/s. It is laid at a slope of 0.0001. If at a section in the channel the depth is 1.6m. What is the type of profile that exits between this section and another section where the depth of flow is 2m. Take n = 0.015 and critical depth is 0.976? **[NOV/DEC 2011,2017]**
14. Write the gradually varied flow equation in an open channel flow. Deduce the equation for a wide rectangular channel using Manning's and Chezy's equations.
15. Explain with the neat diagram the surges produced when (1) a sluice gate is suddenly raised and (2) sluice gate lowered.

PART C – C

1. Explain direct step method for computing the length of the water surface profile**. [NOV/DEC 2007]**
2. Define the terms: (1) Afflux and (2) back water curve. Derive an expression for the length of the back water curve. **[April/May 2014]**
3. What are the methods used for determining the length of backwater curve? Explain each method.
4. Derive the basic differential equation of spatially varied flow with decreasing discharge.
5. Derive the basic differential equation of spatially varied flow with increasing discharge.
6. Derive the dynamic equations of the Gradually varied flow.**(NOV/DEC 2018)**

UNIT-III RAPIDLY VARIED FLOW

Part A

1. What is a draw down curve? [APRIL/MAY 2010, APR/MAY 2018]

When the depth of flow decreases along the flow direction $\frac{dy}{dx}$ becomes negative and the surface profile is called draw down curve.

2. Define the Afflux.[NOV/DEC 2008, MAY/JUNE 2014, APR/MAY 2018]

Afflux is defined as the maximum increase in the water level due to obstruction in the path of flow of water.

3. What are meant by positive and negative surges? [MAY/JUNE2012, [NOV/DEC 2017]

a. Positive surge – a surge producing increase in depth
b. Negative surge – a surge producing decrease in depth.

4. What are the uses of formation of hydraulic jump in a channel? [APRIL/MAY 2010,MAY/JUNE 2015,MAY/JUNE 2016, NOV/DEC 2017, APR/MAY 2018]

a. To dissipate excessive energy.
b. To increase the water level on the downstream of a hydraulic structure.
c. To reduce the net uplift force by increasing the downward weight due to increased depth.
d. To increase the discharge from a sluice gate by increasing the effective head causing flow.
e. To provide a control section.
f. For aeration of drinking water.
g. For removing air pockets in a pipeline.

5. Write about backwater curves. [MAY/JUNE 2014, NOV /DEC 2016, APR/MAY 2018]

The profile of the rising water in the upstream side of the dam is called backwater curve. The distance along the bed of the channel between sections where the water is having maximum height and at the point where the water starts rising up is known as length of backwater curve.

6. State the flow conditions for the occurrence of hydraulic jump. [MAY/JUNE 2015]

a) When the depth of flow is forced to change from a super critical depth to subcritical depth
b) Froude's Number decrease from >1 to <1.
c) Jump will not occur when Froude's Number is <1.
d) Jump will not occur from sub-critical to super critical flow.

7. What are surges in open channel flow? State the types? [MAY/JUNE 2015,MAY/JUNE 2016]

When the flow properties, such as discharge or depth varies suddenly is called surge. Example: sudden closure of gate.

Types: i) Positive surge ii) Negative surge

8. Define: Impulse momentum principle. [MAY/JUNE 2016]

F= m x a
F= mx dv/dt
F= d(mv)/ dt
F.dt = d(mv)

Which is known as the impulse-momentum equation and states that the impulse of a force F acting on a fluid of mass m in a short interval of time dt is equal to the change of momentum d(mv) in the direction of force.

9. Write down the application of transition.[MAY/JUNE2017]

Transition means a change of channel cross section. Transition in open channel flow is made to measure discharge of channel. Generally, discharge Q=Area (A) x Velocity (V). For discharge calculation, both cross section of flow and velocity are necessary. With the help of channel transition, the discharge of water is obtained from measured flow cross section dimensions and specific energy equations.

10. What are the location of hydraulic jump and why it is being done?

A hydraulic jump that causes eddies and turbulence, that causes scouring of the bed of the channel if the bed material is weak. It is generally required to locate exactly the position at which the hydraulic jump occurs so that the bed protection works may be provided in the vicinity of that point. Its location include

a. Jump below a sluice gate.
b. Jump at the toe of a spillway.
c. Jump on a glacis.

11. Define energy dissipation. [MAY/JUNE2017, NOV/DEC 2014]

When the hydraulic jump takes place, a loss of energy occurs due to eddy formation and turbulence. This loss of energy or energy dissipation is equal to the difference of specific energies at two different sections.

12. Define transition depth.[NOV/DEC 2008, APR/MAY 2018]

For rate of flow calculation, instead of reducing width of channel, depth of water is lowered or increased to certain heights by providing hump is called transition in depth. By providing hump on the channel, the water level will be lowered over the hump for subcritical flow and water level will be increased for super critical flow.

13. Give the relationship between length and depth of hydraulic jump.

From experiments, for a rectangular channel, the length of hydraulic jump is equal to 5 to 7 times the height of the hydraulic jump.

$L = 5 \, to \, 7 \, (y_2 - y_1)$

14. What is the use of stilling basin?

Stilling basins are used for the dissipation of excess energy in hydraulic structures. For efficient dissipation of the energy, the Froude number of the incoming flow(F_1) should be between 4.5 and 9.0. In this case, a good stable jump is formed.

15. Write the expression for hydraulic jump?

$$y_2 = \frac{y_1}{2}\left(\sqrt{1+8(F_1)^2 p} - 1\right)$$

Where

Depth of hydraulic jump=y_1-y_2

y_1=Depth of flow at section 1-1

y_2 =Depth of flow at section 2-2

F_1=Froude number at section 1-1

16. Define loss of energy due to hydraulic jump.

$$h_L = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

Where

y_1=depth of flow at section 1-1

y_2=depth of flow at section 2-2

17. Why momentum equation only used for rapidly varied flow problems?

Generally, the hydraulic jump occurs at the downstream side of a surplus weir, when a super critical flow and a sub critical flow meet. Both the flows join in an extremely turbulent manner which causes large energy losses because the large energy loss for which energy equation cannot be used for analysis. However, the momentum equation can be used for hydraulic jump analysis.

18. What is the state of flow after the formation of a hydraulic jump? [NOV/DEC 2011]

Streaming or tranquil flow occurs after the formation of hydraulic jump. Shooting of supercritical flow is an unstable flow and it does not continue on the downstream side of a surplus weir. Then this shooting will convert itself into streaming or tranquil flow and hence, the depth of water will increase.

19. What are the assumptions made in the analysis of hydraulic jump? [NOV/DEC 2017]

1. The length of hydraulic jump is small. Consequently, the loss of head due to friction is negligible.
2. The channel is horizontal or it has a very small slope. The weight component in the direction of flow is neglected.
3. The portion of channel in which the hydraulic jump occurs is taken as a control volume. It is assumed that just before and just after the control volume, the flow is uniform and pressure distribution is hydrostatic.
4. The momentum correction factor is unity.

20. Define transition in open channel?

Transition means a change of channel cross section.

a. Provision of a hump or depression along depth.

b. Contraction or expansion of channel width, in any combination

21. What are surges? [APRIL/MAY 2011,2013, NOV/DEC 2012,2013]

When the flow properties such as discharge or depth varying suddenly, it is called surge.

EX: Sudden closure of gate.

22. What is hydraulic jump in horizontal bed channels?[APRIL/MAY 2007,2011, NOV/DEC 2006,2013]

The rise of water level which takes place due to the transformation of the shooting flow into the streaming flow is known as hydraulic jump.

23. What is the formula for power lost by energy dissipation?

Power lost by energy dissipation in kW=gQh_L

Where

g - Acceleration due to gravity=9.81m/s^2

Q -Rate of flow in m^3/s

h_L– Head in m

24. Give the relationship between length and depth of hydraulic jump.

From experiments, for a rectangular channel, the length of hydraulic jump is equal to 5 to 7 times the height of the hydraulic jump.

L= 5 to 7 (y_2 - y_1)

25. Explain the classification of hydraulic jumps.[APRIL/MAY 2010]

Based on Froude number (F), hydraulic jump can be classified into 5 types.

a. **Undulation jump:** The Froude number F ranges from 1 to 1.7 and the liquid surface does not rise shortly but having undulations of gradually decreasing size.

b. **Weak jump:** The Froude number F ranges from 1.7 to 2.5 and the liquid surface remains smooth.

c. **Oscillating jump:** The Froude number F ranges from 2.5 to 4.5 and there is an oscillating jet which enters the jump bottom and oscillates to the surface.

d. **Steady jump:** The Froude number F ranges from 4.5 to 9 and energy loss due to steady jump is between 45 and 70%.

e. **Strong jump:** The Froude number F is greater than 9 and the downstream water surface is rough. Energy loss due to strong jump may be up to 85%.

Part B

1. (i) Explain the classification of hydraulic jumps.
   (ii) A spillway discharges a flood flow at a rate of 7.75 m^3/s per metre width. At the downstream horizontal apron the depth of flow was found to be 0.5 m. What tail water depth is needed to form a hydraulic jump? If a jump is formed, find its type, length, head loss and energy loss as a percentage of the initial energy. **[APRIL/MAY 2010,MAY/JUNE 2016, Nov/ Dec 2016]**
2. i) What are the conditions for the formation of hydraulic jump?
   ii) In a rectangular channel of bed width 0.5 m, a hydraulic jump occurs at a point where depth of flow is 0.15 m and the Froude's number is 2.5. Determine 1. The Specific Energy 2.The critical depth 3.The subsequent depths 4.Loss of head 5. Energy dissipated. [**APRIL/MAY 2012]**
3. (i) Derive an expression for loss of head in Hydraulic Jump.
   (ii) How the discharge measurement done using Standing wave flume without hump. (iii) What are the various types of surges? Explain. **[MAY/JUNE 2013]**
4. (i)Explain how the profiles are classified.
   (ii) Explain the development of M, S and H profiles with neat sketches. **[MAY/JUNE 2013]**
5. (i) Differentiate the 'Gradually varied flow' and 'Rapidly varied flow'.
   (ii) Define the terms 1. Afflux and 2.Back water curve. Derive an expression for the length of the back water curve. **[APRIL/MAY 2014]**
6. A venturiflume is 1.30 m wide at entrance and 0.65 m in the throat. Neglecting hydraulic losses in the flume, calculate the flow if the depths at the entrance and throat are 0.65 m and 0.60 m respectively. A hump is now installed at the throat of height 200 mm, so that a standing wave (hydraulic jump) is formed beyond the throat. What is the increase in the upstream depth when the same flow as before passes through the flume? **[APRIL/MAY/JUNE2014]**
7. Water flows from an under sluice into a very wide rectangular channel. The channel has a bed slope of 1 in 1000. The sluice is regulated to discharge 6 m3/s per m width of channel, the depth of vena contracta being 0.5 m. Will a hydraulic jump form? If so determine its location. Use a single step for the computation with Manning's constant n=0.015. **[MAY/JUNE 2015, MAY/JUNE 2016]**
8. The depth and velocity of flow in a rectangular channel are 1 m and 1.5 m/s respectively. If the rate of inflow at the upstream end is suddenly doubled, what will be the height and absolute velocity of the resulting surge and the celerity of the wave? **[MAY/JUNE 2015]**
9. (i)What is a hydraulic jump? List the assumptions made in the analysis of hydraulic jump. Explain its classification.
   (ii)Discuss the types of surges briefly.[**MAY/JUNE 2016].**
10. Define surge. What are its types? How the energy dissipated? Explain in detail**. [MAY/JUNE 2017, APR/MAY 2018]**
11. Define hydraulic jump. What are its types? How the energy dissipated? Explain in detail. **[MAY/JUNE 2017]**
12. i) Explain the term 'Hydraulic Jump'. Derive an expression for loss of energy due to Hydraulic Jump.
    ii) The depth of flow of water at a certain section of a rectangular channel of 2 m wide is 0.3 m. The discharge through a channel is 1.5 m^3/sec. Determine whether a hydraulic jump will occur, if so, find its height and loss of energy per kg of water. **[NOV/DEC 2007]**
13. Discuss briefly the types of hydraulic jump, its application. **[NOV/DEC 2009]**
14. Explain with a neat diagram the surges produced when
    (i) a sluice gate is suddenly raised (ii) sluice gate is suddenly lowered.
    (ii) Write short notes on : (i) Graphical integration. (ii) Energy dissipation. **[NOV/DEC 2011]**
15. Define hydraulic jump. What are its types? How the energy is dissipated? Explain in detail. **[NOV/DEC 2012]**

16. The depth and velocity of flow in a rectangular channel are 0.90 m and 1.5m/s respectively. If a gate at the downstream end of the channel is abruptly closed, what will be the height and absolute velocity of the resulting surge ? If the channel is 950 m long, how much time will be required for the surge to reach the upstream end of the channel?**(NOV/DEC 2017)**
17. At the bottom of a spillway the velocity and depth of flow are12 m/s and 1.5 m respectively. If the tail water depth is 5.5 m find the location of the jump with repect to the toe of the spillway. What should be the length of the apron to contain this jump? Assume the apron to be horizontal and Manning's n=0.015.**[APR/MAY 2018]**

PART C

1. A Sluice gate discharges $2.5m^3/s$ into a wide horizontal rectangular channel. The depth at the vena-contracta is 0.2m. The tail water depth is 2.0m. Assuming the channel to have a Manning's n=0.015, determine the location of the hydraulic jump. Consider the bed slope as 0.0005**. [APRIL/MAY 2008]**
2. During an experiment conducted on a hydraulic jump, in a rectangular open channel 0.5m wide, the depth of water changes from 0.2m to 0.5m. Determine the discharge in the channel and the loss of head due to the formation of hydraulic jump.**[APRIL/MAY 2009]**
3. Froude number before the jump is 10.0 in a hydraulic jump occuring in a rectangular channel and the energy loss is 3.20m. Estimate the (i) sequent depths and (ii) the discharge. **[NOV/DEC 2008]**
4. Derive the expression for the head loss in a hydraulic jump formed in a rectangular channel.**(NOV/DEC 2017)**

UNIT-IV TURBINES

Part A

1. Classify Impulse turbine according to (a) The direction of flow through the turbine runner (b) The action of water on turbine blades. [MAY/JUNE2010]

(a) The reaction of flow through the turbine runner

i. Tangential flow impulse
ii. Axial flow turbine.
iii. Radial flow turbine.

(b) The action of water on turbine blades.

i. Inward flow
ii. Outward flow

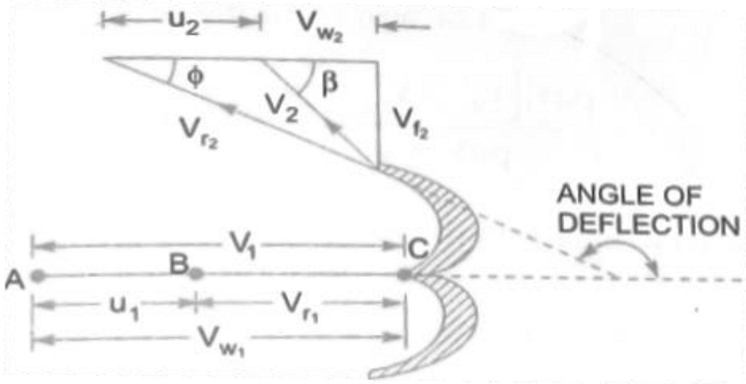
26. Define specific speed of a turbine.[MAY/JUNE2010] [NOV/DEC 2017]

An imaginary turbine identical to actual turbine, but with reduced size so as to develop a unit power under a unit head is called specific turbine and its speed is known is known as specific speed. It develops a unit horse power under unit head.

2. How would you classify turbines based on the direction of flow in the runner?[MAY/JUNE2012,MAY2016]

a) Tangential flow turbine
b) Axial flow turbine.
c) Radial flow turbine.
d) Mixed flow turbine.

3. Draw typical velocity triangles for inlet and outlet of Pelton Wheel.[MAY/JUNE2012, MAY/JUNE2016, NOV/DEC 2016]



V_1-absolute velocity of jet at inlet = $\sqrt{2gh}$

V_2-velocity of jet leaving the vane or bucket
V_{r1}-velocity of jet relative to bucket at inlet
V_{r2}-velocity of jet relative to bucket at outlet
V_{w1}- Velocity of whirl at inlet tip of the bucket
V_{w2}- Velocity of whirl at outlet tip of the bucket
V_{f1}-Velocity of flow at inlet
V_{f2}-Velocity of flow at outlet
u-peripheral velocity of runner, u= $\frac{\pi DN}{60}$
β- angle made by velocity V_2 with the direction of motion of the vane at outlet
ϕ- angle made by V_{r2} with the direction of motion of the vane at outlet and also called vane angle at outlet.

4. **Give examples of reaction turbine. [MAY/JUNE2013]**
   a) Francis turbine
   b) Kaplan turbine.
   c) Propeller turbine.

5. **What are the uses of draft tubes? [MAY/JUNE2013]**
   It increases the efficiency of the turbine.It enables the turbine to be installed above the tail race level without loss of additional hydraulic energy

6. **What is radial flow turbine/Write down the mechanism of radial flow turbine? [NOV/DEC 2012]**
   It's a type of reaction turbine. In a radial flow turbine, the water flows in a radial direction, the velocity vector always remaining in plane perpendicular to the turbine axis. The turbine may be radially inward flow type or radially outward flow type.

7. **Write a short note on cavitation. State its effects. [MAY/JUNE 2014 &MAY/JUNE2011]**
   Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of higher pressure. The major effects are break down of the machine itself due to severe pitting and erosion of blade surface, noise and vibration.

8. **What are the functions of draft tubes? [MAY/JUNE 2014]**
   1) It transforms a large part of high kinetic energy flow into the pressure energy. The energy rejected into tail race is greatly reduced by draft tube.
   2) It increases the head of water by an amount equal to height of the runner outlet above the tail race.

9. **A jet of water 40 mm diameter with a velocity 30m/s, strikes a stationary plate at its normal direction. Determine the force exerted by the jet. [MAY/JUNE 2015]**
   Area of the jet $a = \frac{\pi x 0.05^2}{4}$ = 0.001256 m^2
   Force exerted by the jet, $F = \frac{waV(V-v)}{g}$ = $\frac{9.81x0.001256x30(30-0)}{9.81}$
   =1.130 kN = 113 N

10. **What is meant by reaction turbine? State an example. (MAY/JUNE 2015]**
    In a reaction turbine, the water enters the wheel under pressure and flow over the vanes. As the water, flowing over the vanes, is under pressure, therefore wheel of the turbine runs full and may be submerged below the tail race or may discharge into the atmosphere. The pressure head of water, while flowing over the vanes is converted into velocity head, and is finally reduced to the atmospheric pressure, before leaving the wheel. Eg.Francis and Kaplan turbine.

11. **What is the purpose of providing a casing in turbines? [April/May 2017, APR/MAY 2018]**
    It is an outer cover, which prevents the splashing of water and to discharge the water to the tail race. The pressure inside the casing is maintained at atmospheric by keeping it open.

12. **What is overall efficiency in turbines? [NOV/DEC 2012]**
    It is defined as the ratio of power available at the turbine shaft to the power available from the water jet.
    $$\eta = \frac{Shaft\,Power}{Water\ power} = \frac{P}{wQH}$$

13. **Distinguish between impulse and reaction turbines.**

S.No	Reaction Turbine	Impulse Turbine

1	Only a fraction of the available hydraulic energy is converted into kinetic energy before the fluid enters the runner.	All the available hydraulic energy is converted into kinetic energy by a nozzle and it is the jet so produced which strikes the runner blades.
2	Both pressure and velocity change as the fluid passes through the runner. Pressure at inlet is much higher than at the outlet.	It is the velocity of jet which changes the pressure throughout remaining atmospheric
3	It is not possible to regulate the flow without loss.	It is possible to regulate the flow without loss.
4	It is essential that the wheel should always run full.	It is not essential that the wheel should always run full.
5	The runner must be enclosed within a watertight casing.	The runner is not necessarily to be enclosed within a watertight casing.

14. What is radial flow turbine? [April/May 2017]

If the water flows in the turbine in radial direction then the turbines are known as radial flow reaction turbine. In this type of turbine the energy available at the inlet is combination of pressure energy and minimum kinetic energy. These turbines are kept inside the enclosed chamber, where pressure inside is reduced**.**

If the water flows from outwards to inward (i.e. towards the axis of rotation) through the runner, the turbine is known as Inward Radial flow reaction turbines.

If the water flows from inwards to outwards (i.e. away from the axis of rotation) through the runner, then the turbine is known as Outward Radial flow reaction turbine .

15. The Work done by a fluid on a curved vane per second is 800 Joules .If the angular velocity is 20 radians per second what is the torque? [NOV/DEC 2011]

Work done, P =Torque x Angular velocity

Torque, T= P/ω=800/20= 40 Nm

16. What are the advantages of draft tube? [NOV/DEC 2011]

The pressure at the exist of the runner of a reaction turbine is generally less than the atmospheric pressure. By passing water through the draft tube, the outlet velocity of water is reduced considerably and the gain in useful pressure head is achieved. Thus, the net working head on the turbines increases and therefore, the output of the turbine is also increased.

Draft tube provides a negative suction head at the runner outlet by which it becomes possible to install the turbine above the tailrace level without any loss of head.

17. What are the applications of momentum principles?[Nov/Dec 2011]

The momentum principle is applied to the following fluid flow situations:

1. Force on pipe bends
2. Force exerted by jet of fluid striking against a solid surface.
3. Thrust on a propeller
4. Jet propulsion

18. What are unit quantities in a turbine? What are they used for? [April 2008]

Unit quantities refer to the turbine parameters which are obtained for the particular turbine operated under a unit head. For estimating unit quantities, it is assumed that the efficiency of the turbine remains unchanged. The velocity triangles under the actual working head and any other assumed head are to be similar.

19. What is a draft tube? In which type of turbines it is mostly used? [NOV/DEC 2003,2004]

The tube which increases the outlet velocity of turbines is known as draft tube. So, the head is saved by fitting draft tube.

20. Define Hydraulic Efficiency. [Aril/May 2004, Nov/Dec 2006]

It is defined as the ratio of power developed by the runner to the power supplied by the water jet.

$$\eta = \frac{Power\ developed\ by\ the\ runner}{Power\ \sup plied\ by\ the\ water\ jet}$$

21. Classify turbines based on head. [Nov/Dec 2002]

S.No	**Head of water in metres**	**Type of turbine**
1.	0-25	Kaplan or Francis (preferably Kaplan)
2.	25-50	Kaplan or Francis (preferably Francis)

3.	50-150	Francis
4.	150-250	Pelton or Francis (preferably Francis)
5.	250-300	Pelton or Francis (preferably Pelton)
6.	Above 300	Pelton

22. Write the types of draft tube. [April/May 2011]

Draft tubes are classified into two types.

(i) Straight conical or concentric tube

(ii) Elbow type

23. What is meant by governing of turbines?[NOV/DEC 2007]

The method of maintaining the speed of the turbine is constant irrespective of variation of the load on the turbine known as governing of turbines. The governors regulate the supply of fluid to the turbine in such a way that the speed of the turbine is constantly maintained as far as possible under varying load conditions. The principal method of hydraulic turbine governing is throttle governing or centrifugal governing.

24. What is meant by breaking jets in a Pelton wheel turbine? [NOV/DEC 2017]

Whenever the turbine has to be brought to test the nozzle is completely closed. But the runner of pelton wheel goes on revolving due to inertia. To bring the runner to rest in short time, a small nozzle is provided in such a way that it will direct the jet of water on the back of the buckets. It acts as a brake for reducing the speed of the runner.

25. What are the types of characteristics curves of turbine?(APR/MAY 2018)

The characteristics curves obtained are the following

a) Constant head curves or main characteristic curves

b) Constant speed curves or operating characteristic curves

c) Constant efficiency curves or Muschel curves

Part B

1. A Pelton turbine is required to develop 9000 kW when working under a head of 300 m. The runner may rotate at 500 rpm. Assuming the jet ratio as 10, speed ratio as 0.46 and overall efficiency as 85%, determine the following :(1) Quantity of water required.(2) Diameter of the wheel.(3) Number of jets.(4) Number of buckets.

   (ii) Write briefly about the classification of turbines. **[MAY/JUNE2010]**

2. (i) Draw the characteristic curves of turbines and explain.

   (ii) An inward flow reaction turbine operates under a head of 25 m running at 200 rpm. The peripheral velocity of the runner is 20 m/s and the radial velocity at the runner exit is 5 m/s. If the hydraulic losses are 20% of the available head, calculate:(1) The guide-vane exit angle.(2) The runner-vane angle.(3) The runner diameter.(4) The specific speed, if the width of the runner at the periphery is 30 cm and (5) The power produced by the turbine. **[APRIL/MAY 2010]**

3. **(i)** Distinguish between impulse and reaction turbines.

   (ii)A Pelton wheel is required to develop 8825 kW when working under the head of 300m. The speed of the pelton wheel is 540 r.p.m. The coefficient of velocity is 0.98 and the speed ratio is 0.46. Assuming jet ratio as 10 and the overall efficiency as 84% Determine:

   (a) The number of jets

   (b) The diameter of the wheel

   (c) The quantity of water required.[**APRIL/MAY 2012,NOV/DEC 2016]**

4. (i) What are the various types of draft tubes?

   (ii) A Francis turbine is to be designed to develop 360 kW under a head of 70 m and a speed of 750 rpm. The ratio of width of runner to diameter of runner ‘n’ is 0.1. The inner diameter of the runner is half the outer diameter. The flow ratio is 0.15. The hydraulic efficiency is 95% and the mechanical efficiency is 84%. Four percent of the circumferential area of the runner is to be occupied by the thickness of vanes. The velocity of flow is constant and the discharge is radial at exit.Determine(i)The diameter of the wheel;(ii)The quantity of water supplied(iii)The guide vanes angle at inlet(iv)Runner vane angles at inlet and exit. [**APRIL/MAY 2012]**

5. (i)A jet of water having a velocity of 40m/s strikes a curved vane, which is moving with a velocity of 20m/s. The jet makes an angle of 30^o with the direction of motion of vane at inlet and leaves at an angle of 90^o to the direction of motion of vane at outlet. Draw the velocity triangles at inlet and outlet and determine the vane angles at inlet and outlet so that the water enters and leaves the vane without shock.

   (ii)Derive the impulse momentum principle.[**APRIL/MAY 2014]**

6. (i) A Pelton wheel is to be designed for the following specification

   Power (brake or shaft) – 9560 kW, Take C=0.985 Speed ratio =0.45

   Head – 350 metres

Speed – 750 rpm
Overall efficiency – 85%
Jet diameter – not to exceed $1/6^{th}$ of the wheel diameter
Determine the following (i) The wheel diameter (ii)Diameter of the jet and (iii)The number of jets required.
(ii) Write down the difference between radial flow and axial flow turbine. **[APRIL/MAY 2014]**

7. A Kaplan turbine is to be designed to develop 9000 kW. The net available head is 5.6m. The speed ratio is 2.09 and the flow ratio is 0.68. The overall efficiency is 86% and the diameter of the boss is one third the diameter of the runner. Determine the diameter of the runner, speed and specific speed of the turbine. **[MAY/JUNE 2015, NOV/DEC 2017, APR/MAY 2018]**
8. A Pelton wheel is to be designed for the following specifications: Shaft power =11,772 kW, Head = 380 m; Speed =750 rpm; overall efficiency=80%; Jet diameter is not to exceed 1/6 of the wheel diameter. Determine i] Wheel diameter ii] Number of jets required iii] Diameter of jet. Assume K_v=0.985 and K_u=0.45**. [MAY/JUNE 2015]**
9. (i)Write briefly about the classification of turbines.
   (ii)A Pelton wheel is required to develop 8825 kW when working under the head of 300m. The speed of the pelton wheel is 540 r.p.m. The coefficient of velocity is 0.98 and the speed ratio is 0.46. Assuming jet ratio as 10 and the overall efficiency as 84% Determine:
   1) The number of jets
   2) The diameter of the wheel
   3) The quantity of water required.[**MAY/JUNE 2016, NOV/DEC 2016]**
10. A jet of water having a velocity of 30m/s strikes a series of radial curved vanes mounted on a wheel which is rotating at 300rpm. The jet makes an angle 30^0 with the tangent to the wheel at inlet and leaves the wheel with a velocity of 4m/s at an angle of 120^o to the tangent of the wheel at outlet. Water is flowing from outward in a radial direction. The outer and inner radii of the wheel are 0.6m and 0.3m respectively. Determine: 1. Vane angle at inlet and outlet 2. Work done per second per kg of water 3. Efficiency of the wheel.[**MAY/JUNE 2016]**
11. (i) Distinguish between impulse and reaction turbines.
   (ii)Define the following for a turbine:
   b. Manometric Efficiency
   c. Volumetric Efficiency
   d. Mechanical Efficiency **[MAY/JUNE 2017]**
12. A Kaplan turbine runner is to be designed to develop 8600KW. The net available head is 6.6m. If the speed ratio = 2.09, flow ratio=0.6, overall efficiency 84% and the diameter of the boss is 1/3 the diameter of the runner. Find the diameter of the runner, its speed and the specific speed of the turbine. **[MAY/JUNE 2017]**
13. (i) Explain in detail about the main parts of Pelton wheel turbine.
   (ii) A Pelton wheel is having a mean bucket diameter of 1 m and is running at 1000 rpm. The net head on the Pelton wheel is 700 m. If the side clearance angle is 15 and discharge through nozzle is 0.1 m^3/s, find: 1. Power available at the nozzle and 2. Hydraulic efficiency of the turbine.**[NOV/DEC 2012, APR/MAY 2018]**
14. (i). Derive expressions for safe setting height of reaction turbine and efficiency of draft tube.
   (ii). A jet of water 30mm diameter strikes a hinged square plate at its centre with a velocity of 20m/s. The plate is deflected through an angle of 20˚. Find the weight of the plate. If the plate is not allowed to swing, what will be the force required to at the lower edge of the plate to keep the plate in vertical position. **[NOV/DEC 2011]**

15. **(i)** Distinguish between impulse and reaction turbines.
   (ii)A Pelton wheel is required to develop 8825 kW when working under the head of 300m. The speed of the pelton wheel is 540 r.p.m. The coefficient of velocity is 0.98 and the speed ratio is 0.46. Assuming jet ratio as 10 and the overall efficiency as 84% Determine:
   1) The number of jets
   2) The diameter of the wheel
   3) The quantity of water required.[**NOV/DEC 2016]**

16. 200 litres of water per second are supplied to an inward flow reaction turbine. The head available is 11m. The wheel vanes are radial at inlet and intlet diameter is twice as the outlet diameter. The velocity of flow is constant and is equal to 1.85m/s. The wheel makes 350rpm. Find the guide vane angle, inlet and outlet diameter of wheel, width of wheel at inlet and exit. Neglect the thickness of vanes and assume discharge is radial. Take speed ration as 0.7.

PART C

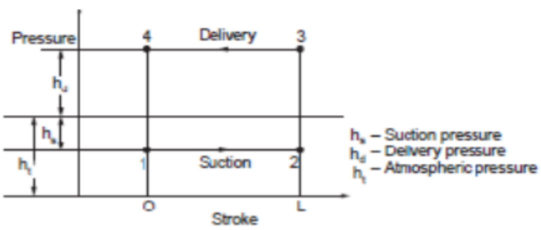
1. A Pelton wheel is required to develop 9530 kW when working under the head of 300m. The speed of the pelton wheel is 550 r.p.m. The coefficient of velocity is 0.97 and the speed ratio is 0.48. Assuming jet ratio as 10 and the overall efficiency as 85% Determine:
   ii. The number of jets
   iii. The diameter of the wheel
   iv. The quantity of water required. **[MAY/JUNE 2017]**
2. (i) How will you classify turbines? Give examples and what is the basis of selection of a turbine at a particular place. (ii) What is a draft tube? Why is it used in a reaction turbine? (iii) What is cavitation? How can it be avoided in reaction turbine? **[NOV/DEC 2007]**
3. (i) Determine the speed of a Pelton Wheel, its diameter, number of jet required and the size of each jet if it develops 13800 MHP under a head of 430 m. Its specific speed is 42. Assume necessary suitable values.
   (ii) Explain the momentum principle with its application. **[NOV/DEC 2009]**
4. A straight conical draft tube with inlet diameter 50cm and exit diameter 90cm is of 4m height. The tube is immersed to about 1m in water. The water enters the draft tube with a velocity of 5m/s. Taking friction head loss=20% of velocity head at entry, find the pressure head at the entry, draft tube efficiency and the power lost in fricition.[**April/May 2008]**
5. A Kaplan turbine runner is to be designed to develop 9100 kW. The net available head is 5.6 m. If the speed ratio=2.09, flow ratio = 0.68, overall efficiency 86% and the diameter of the boss is 1/3 the diameter of the runner. Find the diameter of the runner, its speed and the specific speed of the turbine. **[NOV/DEC 2012]**
6. Discuss in detail the various classification of turbines and explain the components and velocity triangles for Pelton wheel turbine.**(NOV/DEC 2017)**
7. What are the characteristics curves in turbines? List the types.Explain in detail with neat sketches.**[APR/MAY 2018]**

UNIT V PUMPS

Part A

1. **Define the term negative slip. How it occurs? [MAY/JUNE 2010, MAY/JUNE 2014, MAY/JUNE2016, NOV/DEC 2016]**
   In most of the cases, $Q_{act}$is less than Q_{th}. But in some times, Q_{act} may be higher than $Q_{th.}$ In such cases, C_d is greater than unity and the slip will be 'negative' in that case, the slip of the pump is known as negative slip. Negative slip is possible, when the delivery pipe is short, suction pipe is long and pump is running at high speed.
2. **Define suction and delivery strokes[MAY/JUNE2011]**
   Suction stroke is when the crank rotates clockwise from inner dead centre (IDC) to outer dead centre(ODC), the piston moves outward to the right and a vacuum is created on the left side of the piston.
   Delivery stroke is when the crank rotates from ODC to IDC, the piston moves inward to left and a high pressure is built up in the cylinder.
3. **What are air vessels? State their purpose. [MAY/JUNE 2015, NOV/DEC 2017]**
   Air vessel is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber. It is used to obtain a continuous supply of water at uniform rate to save a considerable amount of work and to run the pump at high speed without separation

4. **Define specific speed of a pump. [MAY/JUNE2012]**
   The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which will deliver unit quantity (i.e.,) 1litre of liquid per second) against a unit head (i.e., 1 meter)
5. **Draw the indicator diagram for a single acting reciprocating pump. [MAY/JUNE2012, APR/MAY 2018]**



6. **Why cavitation is considered as undesirable phenomenon in pumps?[MAY/JUNE2017]**
   It is considered undesirable phenomenon in pumps due to break down of the machine itself due to severe pitting and erosion of blade surface. It decreases the efficiency of the machine.

Due to sudden collapse of vapour bubble, considerable noise and vibrations are produced. Cavitation can be identified by sudden drop in efficiency, head falls suddenly, more power requirement, noise and vibrations.

7. **Define the term indicator diagram. [MAY/JUNE 2014,DEC 2013 &MAY/JUNE2013]**
Indicator diagram is the graph plotted between pressure head in the cylinder and distance traveled by piston from inner dead centre for one complete revolution of the crank.

8. **What is Priming? How it can be avoided? [MAY/JUNE 2015]**
The delivery valve is closed and the suction pipe, casing and portion of the delivery pipe up to delivery valve are completely filled with the liquid so that no air pocket is left called as priming.

9. **What is manometric head?[MAY/JUNE2016]**
Manometric head is defined as the sum of the actual lift H +the friction losses in the pipes+ Velocity head. $H_m = H + h_f + \frac{v_d^2}{2g}$

10. **What are the causes of cavitation? [NOV/DEC 2016]**
Cavitation includes formation of vapour bubbles of the flowing liquid and collapsing of the vapour bubbles. Formation of vapour bubbles of the flowing liquid take place only whenever the pressure in any region falls below vapour pressure. When the pressure of the flowing liquid is less than its vapour pressure, the liquid starts boiling and vapour bubbles are formed. These bubbles are carried along with the flowing liquid to higher pressure zones where these vapours condense and bubbles collapse.

11. **What is an indicator diagram? [MAY/JUNE2017]**
Indicator diagram is nothing but a graph plotted between the pressure head in the cylinder and the distance traveled by the piston from inner dead center for one complete revolution of the crank.

12. **Compare and contrast Centrifugal and Reciprocating pumps.[MAY/JUNE2006]**

Centrifugal pump	Reciprocating pump
Pumps work under the principle of centrifugal action.	Pumps work under the reciprocating action.
Impellers and casing are used	Piston and cylinder are used.
Simple in construction, because of less number of parts	Construction is complex, because of more number of parts
Suitable for large discharge and smaller heads.	Suitable for less discharge and higher heads.
Less wear and tear	More wear and tear
Maintenance cost is less	Maintenance cost is more
Needs priming	Dos not need priming
It has less efficiency	It has more efficiency
Its delivery is continuous	Its delivery is pulsating.

13. **What are positive displacement pump and roto dynamic pump?[MAY/JUNE2007]**
A positive displacement pump operates on the principle of actual displacement or pushing of liquid by a piston or plunger which reciprocates in a closely fitting cylinder. Rotary dynamic pumps resemble such as centrifugal pumps in appearance but the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps.

14. **What are the types of casing and impellers in centrifugal pump? [NOV/DEC 2012,2016]**
Types of Casing:
(i)Volute casing,(ii)Vortex casing,(iii)Volute casing with guide blades.
Types of Impellers:
(i)Shrouded or closed impeller,(ii)semi open type impeller,(iii)open impeller.

15. **What is the function of foot valve in a pump?[NOV/DEC 2011]**
The foot valve is a one-way valve located above the strainer into the suction pipe. It is used to fill the pump with liquid, before it is started (i.e., priming) and it prevents back flow when the pump is stopped.

16. **What are the types of characteristics curves?**
    - Main characteristic curve
    - operating characteristic curves
    - constant efficiency or Muschel curves
    - constant head and constant discharge curves.

17. **Mention the main components of reciprocating pump. [NOV/DEC 2002]**

a. Piston or plunger
b. Suction and delivery pipes.
c. Crank and connecting rod.

18. What is meant by multistage pump?[NOV/DEC 2007]
The flow rate or head of fluid obtained is not enough with one pump. So, multiple pumps have to be used, In order to increase either flow rate or head of discharge, pumps are connected in series or in parallel.

19. Define the term negative slip in reciprocating pump. [NOV/DEC 2016]
Slip is defined as the difference between theoretical discharges and actual discharge. If actual discharge is greater than theoretical discharge negative value is found this negative value is called negative slip.

20. State any two precautions against cavitations.
a) The pressure should not be allowed to fall below its vapour pressure.
b) Special material coatings can be given to the surfaces where the caviations occurs.

21. What is meant by multistage pump? [NOV/DEC 2007]
The flow rate or head of fluid obtained is not enough with one pump. So, multiple pumps have to be used. In order to increase either flow rate or head of discharge, pumps are connected in series or parallel.

22. Write the equation for specific speed for pumps and turbines [APRIL/MAY 2009,2006]
Specific speed of pumps, $N_s=\frac{N\sqrt{P}}{H_m^{\frac{5}{4}}}$

Specific speed of turbines, $N_s=\frac{N\sqrt{Q}}{H_m^{\frac{3}{4}}}$

Where
N=Speed of the turbine or pump
P=Power developed
Q=Discharge
H_m=Manometric head

23. What is the maximum theoretical suction head possible for a centrifugal pump?[APRIL/MAY 2010]
The maximum theoretical suction head possible for a centrifugal pump is 10.33m.

24. The difference between the water levels in the sump and the overhead tank is H. What is the total head to be generated by the pump for pumping the liquid?[NOV/DEC 2011]

$$\text{Total head} = H + \text{Losses in pipes} + \frac{V_d^2}{2g}$$

25. What are rotary pump? Give examples. [APRIL/MAY 2003, APR/MAY 2018]
Rotary pumps resemble such as centrifugal pumps in appearance. But, the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps. So, it has the combined advantages of both centrifugal and reciprocating pumps. The various types of rotary pumps are
1. External pump
2. Internal gear pump
3. Lobe pump
4. Vane pump

26. What is meant by Double acting reciprocating pump? [NOV/DEC 2017]
A double acting pump is one which has two suction valves, delivery valves and two suction and dlivery pipes. It is a type of positive displacement pump in which plinger or piston moves back and forth in a closely fitted cylinder, displaces a fiven volume of water for each stroke.

Part B

1. With the help of neat sketches, explain the features of a volute type and a diffusion type centrifugal pump. **[MAY/JUNE2010, NOV/DEC 2016, APR/MAY 2018]**
2. (i) Explain with a neat sketch, the working principles of a double acting reciprocating pump.
(ii) A single-acting reciprocating pump, running at 60 rpm is discharging 0.02 cumecs of water. The pump has a stroke length of 350 mm and plunge diameter of 250 mm. Determine
(a) The theoretical discharge of the pump
(b) Coefficient of discharge

(c) Slip and percentage slip of the pump **[APRIL/MAY 2012]**

3. **(**i) What is meant by “priming a centrifugal pump” and why it is needed?
(ii)Calculate the vane angle at the inlet of a centrifugal pump impeller having 200mm diameter at inlet and 400 mm diameter at outlet. The impeller vanes are set back at angle of 45^o to the outer rim and the entry of the pump is radial. The pump runs at 1000 rpm and the velocity of flow through the impeller is constant at 3m/s. Also, calculate the work done per kN of water and the velocity as well as direction of the water at outlet. **[APRIL/MAY 2014]**

4. A Centrifugal pump delivers salt water against a net head of 15m at a speed of 100rpm. The vanes are curved backward at 30° with the periphery. Obtain the discharge for an impeller diameter of 30cm and outlet width of 5cm at a manometric efficiency of 90%.**[MAY/JUNE2010]**
(i) Draw the indicator diagram of a reciprocating pump for the following cases:
   i. Without air vessels on both suction and delivery sides.
   ii. With air vessel only on suction side.
(ii) For a hydraulic machine installed between *A* and *B*, the following data is available:

	At *A*	**At*B***
Diameter	20 cm	30 cm
Elevation	105 m	100 m
Pressure	100 kPa	200 kPa

The direction of flow is from *A* to *B* and the discharge is 200 litres per second. Is the machine a pump or a turbine? **[APRIL/MAY 2010]**

5. (i)A single acting reciprocating pump (with no air vessel) has a plunger of 80 mm diameter and a stroke of 150 mm. It draws water from a sump 3 m below the pump axis through a suction pipe 30 mm diameter and 4.5 m long. If separation occurs at a pressure of 80kPa below atmospheric pressure, find the maximum speed at which the pump may be operated without separation. Assume that the plunger moves with simple harmonic motion.
(ii) With the aid of an indicator diagram, discuss the effect of acceleration on the work done and pressure head of a reciprocating pump. **[APRIL/MAY 2014]**

6. A centrifugal pump has the following characteristics:
Outer diameter of impeller = 800mm
Width of impeller vanes at outlet = 100 mm
Angle of impeller vanes at outlet = 40°
The impeller runs at 550 rpm and delivers 0.98 m^3/s under an effective head of 35 m. A 500 kW motor is used to drive the pump. Determine the manometric, mechanical and overall efficiencies of the pump. Assume water enters the impeller vanes radically at inlet. **[MAY/JUNE 2015]**

7. (i) Define (i)Manometric efficiency, (ii)Volumetric efficiency, (iii)Mechanical efficiency, (iv)Overall efficiency of Centrifugal pump
(ii) A centrifugal pump has the following characteristics:
Outer diameter of impeller = 450mm
Inner diameter of impeller = 200mm
Angle of impeller vanes at outlet = 25°
The impeller runs at 1440 rpm and the velocity of flow through the impeller is constant and equal to 2.5 m/s. Determine
   (a) Vane angle at inlet
   (b) Work done per unit weight
   (c) The angle, absolute velocity of water at exit makes with the tangent **[APRIL/MAY 2012]**

8. A double-acting reciprocating pump, running at 40 rpm is discharging 1 m3/s water. The pump has a stroke length of 400 mm and piston diameter of 200 mm. The delivery and suction head are 20 m and 5 m respectively. Find the slip of the pump and power required to drive the pump. **[MAY/JUNE 2015]**

9. A three stage centrifugal pump has impellers 400mm in diameter and 200mm wide at outlet. The vanes are curved back at the outlet at 45^0 and reduce the circumferential area by 10%. The manometric efficiency is 90% and the overall efficiency is 80%.Determine the heat generated by the pump when running at 1000rpm delivering 50lps.What should be the shaft horse power?**[MAY/JUNE2016]**

10. What is a reciprocating pump? Describe the principle and working of a reciprocating pump with a neat sketch.**[MAY/JUNE2016]**
11. **(**i) List the factors involved in the selection of pump.
    (ii) Draw and explain the Muschel curves of pump. **[MAY/JUNE2017]**
12. Explain with a neat sketch, the construction details and working principles of a reciprocating pump**. [MAY/JUNE2017]**
13. With the help of neat sketches, explain the features of a volute type and a diffusion type centrifugal pump. **[NOV/DEC 2016]**
14. A single-acting reciprocating pump discharges 4.5 litres per second with cylinder bore diameter 200 mm and stroke length of 300 mm. The pump runs at 350 rpm and lifts water through a height 25 m. The delivery pipe is 30 m long and 100 mm in diameter. Determine (i)The theoretical discharge of the pump,(ii)Theoretical power required to run the pump,(iii)Percentage slip of the pump **[NOV/DEC 2009, APR/MAY 2018]**
15. A jet of water 75mm diameter with a velocity of 20m/s strikes normally a flat smooth plate. Determine the force exerted on the plate if,
    (i) The plate is at rest.
    (ii) The plate is moving in the same direction as the jet with a velocity of 6m/s. Also determine the work done per unit time on the plate. **[NOV/DEC 2016]**
16. The cylinder bore diameter of a single acting reciprocating pump is 150 mm and its tstroke is 350 mm. The pump runs at 60 rpm and lifts water through 25m. The delivery pipe is 22m long and 100 mm in diameter. Find the therotical discharge and ower of the pump. If actual discharge is 4.2lps, find the percentage of slip. Also deternine the acceleration head at the beginning and middle of the delivery stroke.**(NOV/DEC 2017)**
17. A centrifugal pump has a suction lift of 1.5 ma nd delivery tank is 13.5 m abovethe pump. The velocityof water in the delivery pipe os 1.5 m/s. The radial velocity of flow through the wheel is 3 m/s and the tangent to the vane at exit from the wheel makes an angle of 120^o with the direction of motion. Assuming that the water enters radially and neglecting friction and other losses, determine (i) Velocity of wheel at exit (ii) Velocity and pressure head at exit from the wheel and (iii) Direction of fixed guide vanes. [**APR/MAY 2018]**

PART C

1. Write in detail about the application of hydraulic devices (any five). **[MAY/JUNE2017]**
2. A jet of water of diameter 100mm moving with a velocity of 30m/s strikes a curved fixed symmetrical plate at the centre. Find the force exerted by the jet of water in the direction of the jet, if the jet is deflected through an angle of 120° at the outlet of the curved plate. **[NOV/DEC 2016]**
3. (i) With a neat diagram explain the working of jet pump.
   (ii) Determine the total head, capacity, and overall efficiency of a single acting three throw pump with diameter of each cylinder = 28 cm, stroke = 42 cm, speed = 120 rpm, suction head = 2.5m, suction pipe diameter = 20cm, suction pipe length = 5 m , delivery head = 12m, delivery pipe diameter = 15cm, length of delivery pipe = 18 m, coff. of friction = 0.008, and Shaft power = 65kW. Air vessel is provided with both suction and delivery pipes. **[NOV/DEC 2011]**
4. Show that the pressure rise in the impeller of a centrifugal pump is given by $[V_f + u_1^2 - V_{f1}^2 \operatorname{cosec}^2 \Phi]/2g$ provided the frictional and other losses in the impeller are neglected.**[NOV/DEC 2017]**
5. (i) What is reciprocating pump? Describe the principle and working of a single acting reciprocating pump.
   (ii)A single-acting reciprocating pump, running at 30 rpm is discharging 0.012 m^3/s water. The pump has a stroke length of 50 cm and piston diameter of 25 cm. Determine (i)The theoretical discharge of the pump, (ii) Coefficient of discharge (iii) Slip and percentage slip of the pump [**NOV/DEC 2007]**
6. Derive and expression for the pressure head due to acceleration of the piston of a reciprocating pump, assuming motion of the piston to be SHM.**(NOV/DEC 2017)**
7. Explain in detail about the working of air vessel **[APR/MAY 2018]**