UNIT IV BOUNDARY LAYER

1. Mention the range of Reynold's number for laminar and turbulent flow in a pipe.

If the Reynolds number is less than 2000, the flow is laminar. But if the Reynold's number is greater than 4000, the flow is turbulent flow.

2. What does Haigen-Poiseulle equation refer to?

The equation refers to the value of loss of head in a pipe of length 'L' due to viscosity in a laminar flow.

3. What is Hagen poiseuille's formula?

$$\mathbf{(P_1-P_2) / \rho g = h_f = 32\ \mu \bar{U} L / \rho g D^2}$$

The expression is known as Hagen poiseuille formula.

Where P_1-P_2 / ρg = Loss of pressure head, Ū= Average velocity, μ = Coefficient of viscosity,
D = Diameter of pipe,
L = Length of pipe

4. Write the expression for shear stress?

Shear stress ζ = - (∂p/∂x) (r/2)
ζmax = - (∂p/∂x) (R/2)

5. Give the formula for velocity distribution: -

The formula for velocity distribution is given as

$$\mathbf{u = - (1/4\ \mu) (\partial p/\partial x) (R^2 - r^2)}$$

Where R = Radius of the pipe,
r = Radius of the fluid element

6. Give the equation for average velocity: -

The equation for average velocity is given as

$$\mathbf{\bar{U} = - (1/8\mu) (\partial p/\partial x) R^2}$$

Where R = Radius of the pipe

7. Write the relation between Umax and Ū?

$$\mathbf{U_{max} / \bar{U} = \{ - (1/4\ \mu) (\partial p/\partial x) R^2 \} / \{ - 1/8\mu\ (\partial p/\partial x) R^2 \}\quad U_{max} / \bar{U} = 2}$$

8. Give the expression for the coefficient of friction in viscous flow?
   Coefficient of friction between pipe and fluid in viscous flow

$$f = 16/ Re$$

   Where, f = Re = Reynolds number

9. What are the factors to be determined when viscous fluid flows through the circular pipe?

   The factors to be determined are:
   i. Velocity distribution across the section.
   ii. Ratio of maximum velocity to the average velocity.
   iii. Shear stress distribution.
   iv. Drop of pressure for a given length

10. Define kinetic energy correction factor?

Kinetic energy factor is defined as the ratio of the kinetic energy of the flow per sec based on actual velocity across a section to the kinetic energy of the flow per sec based on average velocity across the same section. It is denoted by (α).

K. E factor (α) = K.E per sec based on actual velocity / K.E per sec based on Average velocity

11. Define momentum correction factor (β):

It is defined as the ratio of momentum of the flow per sec based on actual velocity to the momentum of the flow per sec based on average velocity across the section.

β= Momentum per sec based on actual velocity/Momentum Per sec based on average
velocity

12. Define Boundary layer.
    When a real fluid flow passed a solid boundary, fluid layer is adhered to the solid boundary.

Due to adhesion fluid undergoes retardation thereby developing a small region in the immediate vicinity of the boundary. This region is known as boundary layer.

13. What is mean by boundary layer growth?

At subsequent points downstream of the leading edge, the boundary layer region increases because the retarded fluid is further retarded. This is referred as growth of boundary layer.

14. Classification of boundary layer.

(i) Laminar boundary layer,
(ii) Transition zone,
(iii) Turbulent boundary layer.

15. Define laminar boundary layer.

Near the leading edge of the surface of the plate the thickness of boundary layer is small and flow is laminar. This layer of fluid is said to be laminar boundary layer.

The length of the plate from the leading edge, upto which laminar boundary layer exists is called as laminar zone. In this zone the velocity profile is parabolic.

16. Define transition zone.

After laminar zone, the laminar boundary layer becomes unstable and the fluid motion transformed to turbulent boundary layer. This short length over which the changes taking place is called as transition zone.

17. Define turbulent boundary.

Further downstream of transition zone, the boundary layer is turbulent and continuous to grow in thickness. This layer of boundary is called turbulent boundary layer.

18. Define Laminar sub Layer

In the turbulent boundary layer zone, adjacent to the solid surface of the plate the velocity variation is influenced by viscous effects. Due to very small thickness, the velocity distribution is almost linear. This region is known as laminar sub layer.

19. Define Boundary layer Thickness.

It is defined as the distance from the solid boundary measured in y-direction to the point, where the velocity of fluid is approximately equal to 0.99 times the free stream velocity (U) of the fluid.

It is denoted by δ.

20. List the various types of boundary layer thickness.
    a. Displacement thickness(δ^*),
    b. Momentum thickness(θ),
    c. Energy thickness(δ^{**})

21. Define displacement thickness.

The displacement thickness (δ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in flow rate on account of boundary layer formation.

$$\delta^* = \int [\, 1 - (u/U) \,]\, dy$$

22. Define momentum thickness.

The momentum thickness (θ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.

$$\theta = \int [\, (u/U) - (u/U)^2 \,]\, dy$$

23. Define energy thickness

The energy thickness (δ^{**}) is defined as the distance by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account of boundary layer formation.

$$\delta^{**} = \int [\, (u/U) - (u/U)^3 \,]\, dy$$

24. What is meant by energy loss in a pipe?

When the fluid flows through a pipe, it losses some energy or head due to frictional resistance and other reasons. It is called energy loss. The losses are classified as; Major losses and Minor losses

25. Explain the major losses in a pipe.

The major energy losses in a pipe is mainly due to the frictional resistance caused by the shear force between the fluid particles and boundary walls of the pipe and also due to viscosity of the fluid.

26. Explain minor losses in a pipe.

The loss of energy or head due to change of velocity of the flowing fluid in magnitude or direction is called minor losses. It includes: sudden expansion of the pipe, sudden contraction of the pipe, bend in a pipe, pipe fittings and obstruction in the pipe, etc.

27. State Darcy-Weisbach equation **OR** What is the expression for head loss due to friction?

$$h_f = 4flv^2 / 2gd$$

where, h_f = Head loss due to friction (m),
L = Length of the pipe (m),
d = Diameter of the pipe (m),
V = Velocity of flow (m/sec)
f = Coefficient of friction

28. What are the factors influencing the frictional loss in pipe flow?

Frictional resistance for the turbulent flow is,

a. Proportional to v^n where v varies from 1.5 to 2.0.
b. Proportional to the density of fluid.
c. Proportional to the area of surface in contact.
d. Independent of pressure.
e. Depend on the nature of the surface in contact.

29. Write the expression for loss of head due to sudden enlargement of the pipe.

$$h_{exp} = (V_1 - V_2)^2 / 2g$$

Where, h_{exp} = Loss of head due to sudden enlargement of pipe.
V_1 = Velocity of flow at pipe 1;
V_2 = Velocity of flow at pipe 2.

30. Write the expression for loss of head due to sudden contraction.

$$h_{con} = 0.5V^2/2g$$

h_{con} = Loss of head due to sudden contraction.
V = Velocity at outlet of pipe.

31. Write the expression for loss of head at the entrance of the pipe.

$$hi = 0.5V^2/2g$$

hi = Loss of head at entrance of pipe.
V = Velocity of liquid at inlet of the pipe.

32. Write the expression for loss of head at exit of the pipe.

$$ho = V^2/2g$$

where, ho = Loss of head at exit of the pipe.
V = Velocity of liquid at inlet and outlet of the pipe.

33. Give an expression for loss of head due to an obstruction in pipe

Loss of head due to an obstruction

$$\mathbf{V^2 / 2g \left(A / Cc (A-a) - 1 \right)^2}$$

Where, A = area of pipe,

a = Max area of obstruction,

V = Velocity of liquid in pipe

A-a = Area of flow of liquid at section 1-1

34. What is compound pipe or pipes in series?

When the pipes of different length and different diameters are connected end to end, then the pipes are called as compound pipes or pipes in series.

35. What is mean by parallel pipe and write the governing equations.

When the pipe divides into two or more branches and again join together downstream to form a single pipe then it is called as pipes in parallel. The governing equations are:

$$\mathbf{Q_1 = Q_2 + Q_3}$$

$$\mathbf{h_{f1} = h_{f2}}$$

36. Define equivalent pipe and write the equation to obtain equivalent pipe diameter.

The single pipe replacing the compound pipe with same diameter without change in discharge and head loss is known as equivalent pipe.

$$\mathbf{L = L_1 + L_2 + L_3}$$

$$\mathbf{(L/d) = (L_1/d_1^5) + (L_2/d_2^5) + (L_3/d_3^5)}$$

37. What is meant by Moody's chart and what are the uses of Moody's chart?

The basic chart plotted against Darcy-Weisbach friction factor against Reynold's Number (Re) for the variety of relative roughness and flow regimes. The relative roughness is the ratio of the mean height of roughness of the pipe and its diameter (ε/D).

Moody's diagram is accurate to about 15% for design calculations and used for a large number of applications. It can be used for non-circular conduits and also for open channels.

38. Define the terms a) Hydraulic gradient line [HGL] b) Total Energy line [TEL]

Hydraulic gradient line: It is defined as the line which gives the sum of pressure head and datum head of a flowing fluid in a pipe with respect the reference line.

HGL = Sum of Pressure Head and Datum head

Total energy line: Total energy line is defined as the line which gives the sum of pressure head, datum head and kinetic head of a flowing fluid in a pipe with respect to some reference line.

TEL = Sum of Pressure Head, Datum head and Velocity head

PART - B

1. Briefly explain the boundary layer definitions.
2. Find the displacement thickness, the momentum thickness and energy thickness for the velocity distribution in the boundary layer given by $u/U = y/\delta$, where u is the velocity at a distance y from the plate and u = U at $y = \delta$, where δ = boundary layer thickness. Also calculate the value of δ^*/θ.
3. Find the displacement thickness, the momentum thickness and energy thickness for the velocity distribution in the boundary layer given by $u/U = 2 (y/\delta) - (y/\delta)^2$.
4. For the velocity profile $u/U = 2 (y/\delta) - (y/\delta)^2$, find the thickness of boundary layer at the end of the plate and the drag force on one side of a plate 1 m long and 0.8 m wide when placed in water flowing with a velocity of 150 mm/sec. Calculate the value of co - efficient of drag also. Take μ for water = 0.01 poise.
5. For the velocity profile for laminar boundary layer $u/U = 2 (y/\delta) - (y/\delta)^3 + (y/\delta)^4$ obtain an expression for boundary layer thickness, shear stress, drag force on one side of the plate and co – efficient of drag in term of Reynold number.
6. For the velocity profile for laminar boundary flow $u/U = \sin (\pi y/2\delta)$. Obtain an expression for boundary layer thickness, shear stress, drag force on one side of the plate and co – efficient of drag in terms of Reynold number.
7. For the velocity profile for laminar boundary layer $u/U = 3/2 (y/\delta) - 1/2 (y/\delta)^3$ find the thickness of the boundary layer and the shear stress 1.5 m from the leading edge of a plate. The plate is 2 m long and 1.4 m wide and is placed in water which is moving with a velocity of 200 mm per second. Find the total drag force on the plate if μ for water = 0.01 poise.
8. For the velocity profile for turbulent boundary layer $u/U = (y/\delta)^{1/7}$, obtain an expression for boundary layer thickness, shear stress, drag force on one side of the plate and co – efficient of drag in terms of Reynolds Number. Given the stress (ζ_o) for turbulent boundary layer as $\zeta_o = 0.0225 \rho U^2 (\mu/\rho U g)^{1/4}$.
9. Determine the thickness of the boundary layer at the trailing edge of smooth plate of length 4 m and of the width 1.5 m, when the plate is moving with a velocity of 4 m/s in stationary air. Take kinematic viscosity of air as 1.5×10^{-5} m^2/s.
10. For the following velocity profiles, determine whether the flow has or on the verge of separation or will attach with the surface:
    (i) $u/U = 3/2 (y/\delta) - 1/2 (y/\delta)^3$
    (ii) $u/U = 2 (y/\delta)^2 - (y/\delta)^3$
    (iii) $u/U = - 2 (y/\delta) + (y/\delta)^2$