11 CHAPTER

Laminar Flow

Q.1 In a laminar flow between two static parallel plates, the velocity at mid-point is found to be 2.0 m/s. If the space between the plates is 10 cm, then the discharge per unit width (in $m^2/s/m$) will be
(a) 0.01 (b) 0.02
(c) 0.13 (d) 0.20

Q.2 A circular pipe of radius R carries a laminar flow of a fluid. The average velocity is indicated as the local velocity at what radial distance measured from the centre?
(a) 0.50 R (b) 0.71 R
(c) 0.67 R (d) 0.29 R

Q.3 The velocity at which the laminar flow ceases, is known as
(a) approach velocity
(b) lower critical velocity
(c) higher critical velocity
(d) None of these

Q.4 Consider the following statements with reference to steady laminar flow
1. shear stress is zero at the centre.
2. discharge varies directly with viscosity of the fluid flowing .
3. velocity is maximum at the centre.
4. hydraulic gradient varies directly with the velocity.

Which of these statement/s is/are correct?
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) Both 1 and 3 (d) Both 3 and 4

Q.5 On a flat plate, point A is at the mid-section and point *B* is the trailing edge. The shear stresses τ_A at *A* and τ_B at *B* are such that
(a) $\tau_A > \tau_B$
(b) $\tau_B > \tau_A$
(c) $\tau_A = \tau_B$
(d) $\tau_A = \tau_B$ if the boundary layer is laminar

Q.6 In a two-dimensional flow of a viscous fluid couette flow is defined for
(a) pressure-gradient-driven laminar flow between fixed parallel plates
(b) pressure-gradient-driven laminar flow through non-circular duct
(c) pressure-gradient driven laminar flow through pipe
(d) laminar flow between a fixed and a moving plate

Q.7 Consider steady laminar incompressible axi-symmetric fully developed viscous flow through a straight circular pipe of constant cross-sectional area at a Reynolds number of 5. The ratio of inertia force to viscous force on a fluid particle is
(a) 5 (b) 1/5
(c) 0 (d) ∞

Q.8 Assertion (A): For a fully developed laminar flow through a pipe, velocity distribution across any section is parabolic in shape.
Reason (R): The shear stress distribution from the centre line of the pipe upto the pipe surface increases linearly.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.9 The relationship $\frac{dp}{dx} = \frac{d\tau}{dy}$ is valid for

(a) irrotational flow (b) nonuniform flow
(c) uniform flow (d) unsteady flow

Q.10 The pressure gradient of laminar flow between parallel plates at rest is

1. proportional to the dynamic viscosity of the fluid
2. proportional to the mean velocity of flow
3. inversely proportional to the square of the distance between plates

Which of these statement/s is/are correct?

(a) Only 2 (b) Both 1 and 2
(c) Both 2 and 3 (d) 1, 2 and 3

Q.11 Oil of viscosity 1.5 Pa. s and relative density 0.9 flows through a circular pipe of diameter 5 cm with a mean velocity of 1.2 m/s. The shear stress at the wall in Pa is

(a) 360 (b) 288
(c) 180 (d) 144

Q.12 The minimum value of friction factor 'f' that can occur in laminar flow through a circular pipe is

(a) 0.025 (b) zero
(c) 0.064 (d) 0.032

Q.13 A liquid flows in a 30 cm diameter pipe at a Reynolds number of 10^6. If the friction factor is 0.025, the thickness of laminar sublayer, in mm, is

(a) 0.025 (b) 1.00
(c) 0.062 (d) 2.40

Q.14 Oil (μ = 0.44 Pas, ρ = 888 kg/m^3) is filled in the space between two parallel plates which are 18 mm apart. The upper plate is moving at a velocity of 4 m/s. What is the shear stress on the plate?

(a) 97.8 Pa (b) 48.9 Pa
(c) 79.8 Pa (d) 87.Pa

Q.15 A 1 m wide and 3 m long flat plate, held stationary, parallel to the flow direction of a uniform incoming stream of water of velocity 3 m/s, leaves a velocity profile, at its trailing edge, varying linearly from zero at the plate to the free-stream velocity of 3 m/s at 5 cm away from the plate. The water flow is only on one side of the plate. Assuming the pressure to be the same everywhere in the flowing water, the drag force on the plate will be

(a) 75 N (b) 66.7 N
(c) 62.5 N (d) 56.25 N

Q.16 The equation $\tau = -\frac{dp}{dl}\frac{r}{2}$ for flow through circular tubes, where τ is shear stress at distance r from centre, is applicable for

(a) laminar flow only
(b) turbulent flow only
(c) critical flow
(d) both laminar and turbulent flow

Q.17 Consider the following statements:

1. Velocity distribution in a generalized shear flow depends on $\frac{dp}{dx}$ but is independent of moving plate velocity.
2. Shear and pressure gradients (in case of laminar as well as turbulent flow) are inter related through the relationship $\frac{\partial p}{\partial x} = \frac{\partial \tau}{\partial y}$.
3. Momentum correction factor for a laminar flow through a circular pipe is $\frac{4}{3}$.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 2 only

Q.18 The term fully developed laminar flow means that,

(a) the Reynolds number of the flow is critical
(b) the pressure drop in the direction of flow is zero
(c) the velocity profile across the flow has become uniform
(d) the velocity profile does not change in the direction of flow

Q.19 The transition from laminar to turbulent flow in free surface flow occurs when Reynolds number R_e is:

(a) $R_e \simeq 2500$ (b) $R_e \simeq 1500$
(c) $R_e \simeq 600$ (d) $R_e < 1$

Q.20 The horse power transmitted through a pipe is maximum when the ratio of loss of head due to friction and total head supplied is

(a) $\frac{1}{3}$ (b) $\frac{1}{4}$
(c) $\frac{1}{2}$ (d) $\frac{2}{3}$

Q.21 For laminar flow in a circular pipe, the Darcy's friction factor f is equal to

(a) $\frac{16}{R_e}$ (b) $\frac{32}{R_e}$
(c) $\frac{64}{R_e}$ (d) $\frac{80}{R_e}$

Q.22 The Darcy's law for flow through porous media is applicable for

(a) laminar flow
(b) turbulent flow
(c) both laminar and turbulent flow
(d) frictionless fluids

Q.23 For a laminar flow between parallel plates separated by a distance 2h, head loss varies

(a) directly as h (b) inversely as h
(c) directly as h^2 (d) inversely as h^3

Q.24 The highest velocity (in cm/sec) for flow of water of viscosity 0.01 poise to be laminar in a 6 mm pipe is

(a) $\frac{100}{3}$ (b) $\frac{125}{3}$
(c) 50 (d) 200

Q.25 Given that, as flow takes place between two parallel static plates, the velocity midway between the plates is 2 m/s, the Reynold's number is 1200 and the distance between the plates is 10 cm, which of the following statements are true?

1. The velocity of the boundary is 1 m/s
2. The rate of flow is 0.1 m^3/s metre width
3. The flow is turbulent
4. The energy correction factor is 2.0

Select the correct answer using the codes given below:

(a) 2 and 3 (b) 2 and 4
(c) 1 and 3 (d) 1, 2, 3 and 4

Q.26 For laminar flow in a pipe carrying a given discharge, the height of surface roughness is doubled. In such a case, Darcy-Weisbach friction factor will

(a) remain unchanged
(b) be halved
(c) be doubled
(d) increase fourfold

Q.27 In laminar flow, local instability occurs first at a point where

(a) u is maximum
(b) $\frac{du}{dy}$ is maximum
(c) $\rho\frac{uy}{\mu}$ is maximum
(d) $\frac{\rho y^2 \frac{du}{dy}}{\mu}$ is maximum

Q.28 Consider the following with respect to the application of the Navier-stakes equation

1. Laminar flow in circular pipes.
2. Laminar flow between concentric rotating cylinders.
3. Laminar unidirectional flow between stationary parallel plates.
4. Laminar unidirectional flow between parallel plates having relative motion.

Which of these statements is/are correct?

(a) 1 only (b) 2 and 3
(c) 3 and 4 (d) 1, 2, 3 and 4

Q.29 **Assertion (A):** If laminar flow of oil between two points of a given pipe line is doubled, then the power consumption is increased to four times the original power.
Reason (R): In laminar flow through circular pipes, head loss varies directly as the discharge.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

■■■■

Answers Laminar Flow

1. (c)	2. (b)	3. (d)	4. (b)	5. (a)	6. (d)	7. (a)	8. (a)	9. (c)	10. (d)
11. (b)	12. (d)	13. (c)	14. (a)	15. (d)	16. (d)	17. (c)	18. (d)	19. (c)	20. (c)
21. (c)	22. (a)	23. (c)	24. (a)	25. (a)	26. (a)	27. (c)	28. (d)	29. (a)	

Explanations Laminar Flow

1. (c)
The average velocity

$$=\frac{2}{3}\times 2=\frac{4}{3}\ \text{m/s}$$

The discharge per unit width

$$=\frac{4}{3}\times 0.1 = 0.13\ \text{m}^3/\text{s/m}$$

2. (b)
For laminar flow in a circular pipe, the local velocity may be given as

$$u = U_{max}\left[1-\frac{r^2}{R^2}\right] \quad ...(i)$$

For laminar flow in a circular pipe, the average velocity may be given as

$$V = \frac{U_{max}}{2} \quad ...(ii)$$

Equating (i) and (ii), we get

$$\frac{U_{max}}{2} = U_{max}\left[1-\frac{r^2}{R^2}\right]$$

$$\Rightarrow \quad \frac{r^2}{R^2} = 1-\frac{1}{2}$$

$$\Rightarrow \quad r^2 = 0.5\,R^2$$

$$\Rightarrow \quad r = 0.71\,R$$

3. (d)
The velocity at which the flow changes from the laminar to turbulent for the case of a given fluid at a given temperature and in a given pipe is known as critical velocity. The state of flow in between these two types of flow is known as 'transitional state'.

6. (d)
Coutte flow is characterized as flow at very low value of Reynold's number between two parallel plates, one is fixed and other is movable.

7. (a)

$$\text{Reynolds number} = \frac{\text{Inertia force}}{\text{Viscous force}} = 5$$

10. (d)
Pressure gradient of laminar flow between parallel plates at rest is

$$\frac{\Delta p}{L} = \frac{12\mu V}{B^2}$$

11. (b)
The shear stress at any radius, r is given by

$$\tau = -\frac{\partial P}{\partial x}\frac{r}{2}$$

At the pipe wall, $r = R$

$$\tau_0 = -\frac{\partial P}{\partial x}\frac{R}{2}$$

Prossure drop $(p_1 - p_2)$

$$= \frac{32\mu\bar{v}L}{D^2} = \frac{32\times 1.5\times 1.2\times L}{(0.05)^2}$$

$$= 23040\,L\ \text{N/m}^2$$

$$\therefore \quad \tau_0 = \frac{23040L}{L}\times\frac{0.05}{4} = 288\ \text{N/mm}^2$$

$$= 288\ \text{Pa}$$

12. (d)

$$f = \frac{64}{R_a}$$

$$R_a = 2000$$

$$\therefore \quad f = \frac{64}{2000} = 0.032$$

13. (c)
The thickness of laminar sublayer, δ is given by

$$\frac{\delta'}{r_0} = \frac{65.6}{R_a\sqrt{f}}$$

$$\Rightarrow \quad \frac{\delta'}{15} = \frac{65.6}{10^6\times\sqrt{0.025}}$$

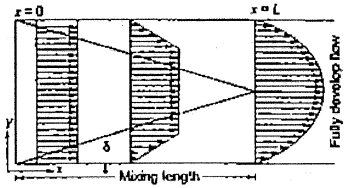
$$\Rightarrow \quad \delta' = 6.22\times 10^{-3}\ \text{cm}$$

$$= 0.062\ \text{mm}$$

14. (d)

$$\tau_0 = \frac{-\partial P}{\partial x}\frac{R}{2}$$

18. (d)
When flow length becomes equal to mixing length, the flow get fully developed and the thickness of boundary layer mets at the pipe centre line. Beyond this length, the velocity distribution is parabolic which is remain parabolic for remaining length.



Hence option (d) is correct.

19. (c)

S. No.	Type	Reynold number $(R_e)_{critical}$
1.	1. Flow around spherical bodies	$R_e = 1$
2.	2. Open channel flow	$R_e = 500$
3.	3. Flow between parallel plates	$R_e = 1000$
4.	4. Pipe flows	$R_e = 2000$
5.	5. Flow over flat plate	$R_e = 3\times 10^5$

For open surface flow (open channel flow),

$$(Re)_{critical} = 500$$

it mean, Laminar flow ... when Re < 500
Turbulent flow ... when Re > 500
Hence most close option is (c).

21. (c)
Darcy - weisbach friction factor
(i) Laminar flow:

$$f = \frac{64}{Re} \quad \text{when Re} < 2000$$

(ii) For turbulent flows:

$$f = \frac{0.316}{(Re)^{1/4}} \quad \text{when Re} > 4000$$

Hence option (c) is correct.

22. (a)
The Darcy's Law for flow through porous media (like soil) is applicable for laminar flow.
Example: Permeability test and consolidation test.

■■■■