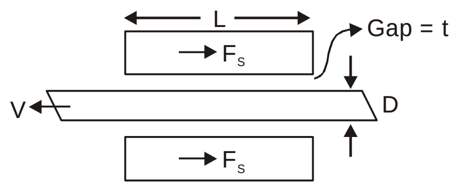
Class Test Solution (FLUID MECHANICS) 02-09-2018

Answer key

1.	(d)	**16.**	(b)	**31.**	(b)	**46.**	(d)	**61.**	(d)
2.	(c)	**17.**	(b)	**32.**	(b)	**47.**	(c)	**62.**	(a)
3.	(c)	**18.**	(b)	**33.**	(b)	**48.**	(c)	**63.**	(b)
4.	(c)	**19.**	(b)	**34.**	(a)	**49**	(d)	**64.**	(b)
5.	(d)	**20.**	(d)	**35.**	(d)	**50.**	(b)	**65.**	(a)
6.	(c)	**21.**	(c)	**36.**	(a)	**51.**	(c)	**66.**	(a)
7.	(b)	**22.**	(d)	**37.**	(c)	**52.**	(c)	**67.**	(a)
8.	(b)	**23.**	(d)	**38.**	(c)	**53**	(d)	**68.**	(c)
9.	(b)	**24**	(c)	**39.**	(b)	**54.**	(d)	**69.**	(d)
10.	(d)	**25.**	(c)	**40.**	(b)	**55.**	(d)	**70.**	(a)
11.	(a)	**26.**	(b)	**41.**	(c)	**56.**	(c)	**71.**	(d)
12.	(b)	**27.**	(c)	**42.**	(d)	**57.**	(a)	**72.**	(b)
13.	(b)	**28.**	(d)	**43.**	(b)	**58.**	(d)	**73.**	(a)
14.	(b)	**29.**	(d)	**44.**	(b)	**59.**	(d)	**74.**	(b)
15.	(d)	**30.**	(a)	**45.**	(a)	**60.**	(c)	**75.**	(d)

CLASS TEST [FLUID MECHANIC] SOLUTIONS

1. (d)



$$\text{Force} = F_S = \mu\left(\frac{V}{t}\right)\pi D \times L$$

$$\frac{F_S}{V} = \frac{\pi D L \mu}{t} = \text{constant}$$

$$\frac{800}{4.5} = \frac{4000}{V}$$

$$V = 5 \times 4.5$$

$$= 22.5 \text{ cm/sec.}$$

2. (c)

Dynamic viscosity is the property of fluid in motion in which one layer of fluid exerts viscous force on the other layer.

Ideal fluids have no viscosity and surface tension and they are incompressible.

Dynamic viscosity is the stress per unit velocity gradient.

3. (c)

$$P = \frac{8\sigma}{d}$$

$$P = \frac{8 \times 0.073}{0.01 \times 10^{-3}} = 58.4 \text{ kN/m}^2$$

Absolute pressure inside the bubble must be = 101.3 + 58.4 = 159.70 kN/m^2

4. (c)

$$h = \frac{4(\cos\theta)\sigma}{\gamma d}, \frac{h_2}{h_1} = \frac{d_1}{d_2}, h_2$$

$$= 7.5 \times 4/3 = 10.0 \text{ mm}$$

5. (d)

6. (c)

Small eddy size → Shorter wave size = Smaller losses.

Lower viscosity → Smaller laminar sublayer → Boundary behaves as hydrodynamically rough → Larger losses.

Large intensity of turbulence - larger losses.

7. (b)

All fluids may be compressed by the application of external force, and when external force is removed, the compressed volumes of fluids expand to their original volumes. compressibility of a fluid is quantitatively expressed as inverse of the bulk modulus of elasticity, K of the fluid which is defined as

$$K = -\frac{dp}{\left(\frac{dv}{v}\right)}$$

$$= \frac{\text{Change in pressure}}{\left(\frac{\text{Change in volume}}{\text{Original volume}}\right)}$$

$$\therefore \quad dv = (-)v\frac{dp}{K}$$

$$= (-) \times 2 \times \frac{10 \times 10^5}{2 \times 10^9} \times 10^3 \text{ litre}$$

$$= (-)\ 1 \text{ litre.}$$

8. (b)

9. (b)

$$\Rightarrow \frac{200}{10} + h + 1 \times 13.6 = \frac{350}{10}$$

$$h = 1.4 \text{ m}$$

$$\Rightarrow \quad \frac{200}{10} + 1.4 + 1 = h_B$$

$$h_B = 22.4 \text{ m of water}$$

10. (d)

$$= [0 + 5 \sin 30^o \gamma_w - 13.6\ \gamma_w \times 5 \sin 30^o] \times 10^{-2} \text{ N/m}^2$$

$$= 5 \sin 30^o\ \gamma_w\ (1 - 13.6) \times 10^{-2}$$

$$= -12.6 \times 5 \times \frac{1}{2} \times \gamma_w \times 10^{-2} \text{ N/m}^2$$

$$= -3090.1 \text{ N/m}^2$$

11. (a)

Both limbs open.

Hence ρ_A and ρ_B being pressure at the top of the limbs

$P_A + \rho_2 g(L - h) - \rho_1 gL = P_B$

$$P_A = P_B = \text{atmospheric pressure}$$

$$\rho_2(L-h) = \rho_1 L$$

$$\Rightarrow (\rho_2 - \rho_1)L = \rho_2 h$$

$$h = \left(1 - \frac{\rho_1}{\rho_2}\right)L$$

$$\Rightarrow h = \left(1 - \frac{2\rho_2}{5\rho_2}\right)L = \frac{3L}{5}$$

12. (b)

According to condition of static equilibrium

$$\frac{\partial P}{\partial y} - \rho g = 0$$

$$\Rightarrow dP = \rho g dy$$

$$\Rightarrow dP = (1000 + 0.01y)g\ dy$$

$$\Rightarrow \int_0^P dP = \int_0^{80} (1000 + 0.01y)\ g\ dy$$

$$\Rightarrow P = \left(1000 \times 80 + 0.01 \times \frac{80^2}{2}\right) \times 9.81$$

$$= 785.11\ \text{kN/m}^2$$

13. (b)

14. (b)

Assuming same height of oil and water in manometer,

$$P_{oil} + h\rho_{oil} g = P_w + h\rho_w . g$$

$$(P_{oil} - P_w) = hg(\rho_w - \rho_{oil})$$

Generally most of common liquid oil has density lower than water hence pressure in oil pipe is higher

15. (d)

16. (b)

$$dp = \int_0^{20} 1000\left(1 + \frac{z^2}{2} + \frac{z^3}{3}\right) dz\ g$$

$$P_2 - P_1 = 1000 \int_0^{20} \left(1 + \frac{z^2}{2} + \frac{z^3}{3}\right) dz\ g$$

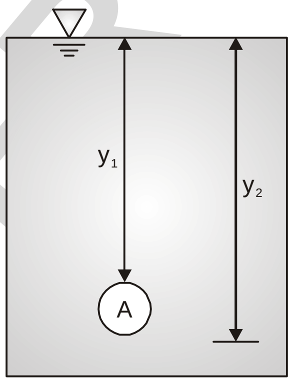
$$= 1000\left(z + \frac{z^3}{6} + \frac{z^4}{12}\right)_0^{20} g$$

$$\Rightarrow 1000 \times \left(20 + \frac{20^3}{6} + \frac{20^4}{12}\right) \times 9.81$$

$\Rightarrow 144.07 \times 10^6\ \text{N/m}^2$.

17. (b)

$$F = \bar{p}A$$



$$\bar{p} = \left(\frac{y_1 + y_2}{2}\right)(\rho g)$$

With $y_1 = 2.75$m, $y_2 = 3.25$m, and $A = \pi r^2$,

$$F = \left(\frac{y_1 + y_2}{2}\right)(\rho g)(A)$$

$$= \left(\frac{2.75m + 3.25m}{2}\right)\left(1000\frac{kg}{m^3}\right)\left(\frac{9.81}{s^2}\right)(1)\pi(0.25m)^2$$

= 5780 N (5.78 kN).

18. (b)

19. (b)

Horizontal force : Force on the projected area normal to x-axis

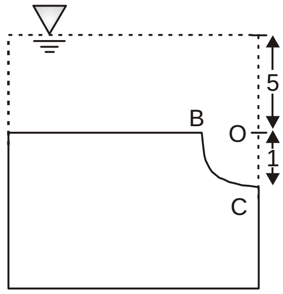
i.e. OC × 2m $\Rightarrow$ 1m × 2 $\Rightarrow$ 2m^2.

$$F_n = \gamma_\omega \bar{h} A$$

But as water is under pressure of 49.05 kN/m^2

i.e. $\frac{49.05}{9.81}$ = 5m of water

$$\bar{h} = 5 + \frac{1}{2} \Rightarrow 5.5\ \text{M}$$



$F_H = 9.81 \times 5.5 \times 2$

$F_H = 107.91$ kN

F_V = vertical force is equal to the weight of the water virtually supported

$$= \gamma_\omega \left(5\times1+\frac{\pi(1)^2}{4}\right)\times 2\,\text{kN}$$

$= 9.81 \times 5.785 \times 2$

$= 113.509$ kN

Resultant force $= \sqrt{F_H^2+F_V^2}$

$$= \sqrt{(107.91)^2+(113.509)^2}$$

$= 156.617$ kN.

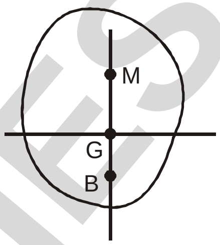
$$\tan\alpha = \frac{F_V}{F_H} \Rightarrow \alpha = \tan^{-1}\left(\frac{113.509}{107.91}\right)$$

$\alpha = 46.44°$

20. (d)

21. (c)

22. (d)



For stable equilibrium the moment caused by weight W and Buoyancy force F_B should balance each other. For this condition M should be above G.

If G is above M, the body will be in unstable equilibrium because moment caused by weight W and buoyancy force add up.

If M and G coincide then neutral equilibrium occurs.

If F_B > W, the body floats.

23. (d)

$$\text{Shape factor} = \frac{m+2}{m} \quad \text{where } m = 5$$

$= 7/5.$

24. (c)

In laminar boundary layer $\delta \propto \sqrt{x}$

$$\frac{3\text{ cm}}{5\text{ cm}} = \frac{\sqrt{x}}{\sqrt{x+2}}$$

$$\frac{9}{25} = \frac{x}{x+2}$$

$9x + 18 = 25x$

$18 = 16x$

$x = 1.125.$

25. (c)

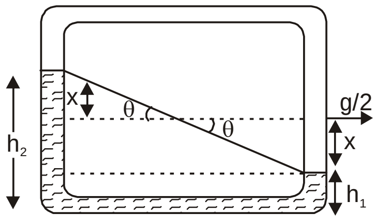
26. (b)

$$\tan\theta = \frac{h_2-h_1}{30} = \frac{a_x}{g} = \frac{g/2}{g}$$

$$h_2 - h_1 = 30\times\frac{1}{2} = 15\text{cm}$$

$2x = 15$ cm

$x = 7.5$ cm



So, $h_1 + x = 15$ cm

$\Rightarrow h_1 = 7.5$ cm.

27. (c)

Forced vortex also known as fly wheel vortex

Free vortex is also known as potential vortex

Combination of free and forced vortex $\rightarrow$ compound or Rankine vortex

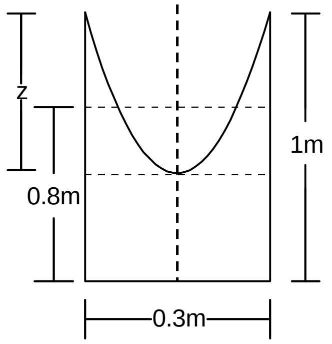
In Tornado $\rightarrow$ inner core is forced vortex

outer core region experiences free vortex.

28. (d)

29. (d)

30. (a)



here $z = 0.4$ m

$$\because \quad z = \frac{w^2r^2}{2g}$$

$$\therefore \quad 0.4 = \frac{w^2 \times 0.15^2}{2g}$$

$$\Rightarrow \quad w^2 = \frac{0.4 \times 2g}{0.15^2}$$

$$\therefore \quad w = 18.676 \text{ rad/sec}$$

31. (b)

Tangential velocity

$$= \frac{\pi DN}{60} \Rightarrow \frac{\pi(1.5)200}{60}$$

$$V_C \Rightarrow 15.707 \text{ m/sec}$$

Circulation $\Rightarrow 2\pi r V_C$

$$\Rightarrow 2\pi\left(\frac{1.5}{2}\right)\times 15.707$$

$$\Gamma \Rightarrow \mathbf{74.022\ m^2/sec}.$$

32. (b)

Streamlines are graphs of constant values for the stream function. The graph shows hyperbolas that are of the form axy = b, where a and b are constants. Thus, of the choices shown, the stream function could only be $\psi = 2xy$.

33. (b)

Velocity potential is a scalar quantity

Velocity potential exists for ideal and irrotational flows.

34. (a)

Statement (2) is valid for eulerian method.

35. (d)

36. (a)

$$u = -\frac{\partial\psi}{\partial y} = -2x$$

$$@(2,-2)u = -4$$

$$v = \frac{\partial\psi}{\partial x}$$

$$v = 2y$$

$$@(2,-2)v = 2 \times -2 = -4$$

$$V = \sqrt{u^2 + v^2}$$

$$= \sqrt{4^4 + 4^2} = 4\sqrt{2}$$

37. (c)

$u = a + by + cy^2$

Boundary conditions are

– at y = 0, u = 0

0 = a + 0 + 0 , a = 0

– at $y = \delta$, u = v

$v = b\delta + cy^2$ ......(i)

– at $y = \delta$, $\frac{du}{dy} = b + 2cy$

$\frac{du}{dy} = 0$ hence $0 = b + 2cy$ ...... (ii)

Using these boundary conditions and solving, (i) & (ii) we get

$$a = 0$$

$$b = 2v/\delta$$

$$c = -v/\delta^2$$

38. (c)

39. (b)

$$\frac{\partial\tau}{\partial y} = \frac{\partial p}{\partial x}.$$

40. (b)

$$h = x\left[\frac{S_h}{S_0} - 1\right]$$

S_h = relative density of monometric fluid

S_h = relative density of flowing fluid

$$h = .25 \times \left[\frac{13.6}{0.8} - 1\right] = 25[17-1]$$

h = 4 m of oil

d_1 = 20 cm

$$a_1 = \frac{\pi}{4}d_1^2 = \frac{\pi}{4}\times 20^2 = 0.0314\,m^2$$

d_2 = 10 cm

$$a_2 = \frac{\pi}{4}\times 10^2 = 78.54\times 10^{-4}\ m^2$$

C_d = 0.98

$$Q = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

Q = 70.43 lit/s.

41. (c)

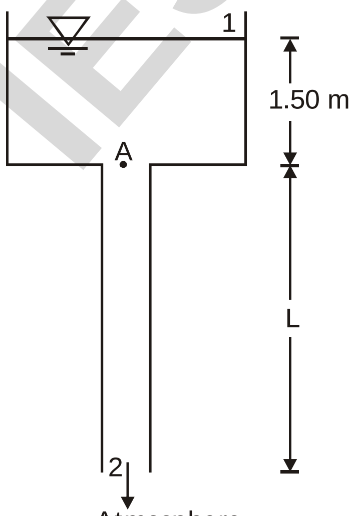
p_A = vapour pressure = 4.00 kPa

$p_1 = p_2$ = atmospheric pressure = 95.48 kPa

Applying Bernoulli's equation across a streamline

between poitns (1) and (A),

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{p_A}{\gamma} + \frac{V_A^2}{2g} + Z_A,$$



$$\text{or } \frac{95.48}{9.81} + 0 + 1.5 = \frac{4.00}{9.81} + \frac{V_A^2}{2g} + 0$$

$\therefore$ V_A = 14.59 m/s

Hence, V_2 = (14.59/2) = 7.29 m/s

42. (d)

Applying Bernoulli's equation across a streamline between points (1) and (2), with datum at (2),

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 \Rightarrow \frac{95.48}{9.81} + 0 + (L + 1.5)$$

$$= \frac{95.48}{9.81} + \frac{(7.29)^2}{2\times 9.81} + 0$$

Hence, L = 2.709 – 1.5 = 1.21 m

43. (b)

44. (b)

$$P = \rho gh,$$

$$v = \sqrt{\frac{2}{\rho}(p_2 - p_1)} = \sqrt{2g(h_2 - h_1)}$$

$$= \sqrt{2\times 9.81\times(0.33 - 0.20)}$$

$$= 1.60 \text{ m/s}$$

45. (a)

Pressure will be low at the top most point as compared to lowest point so thrust will be upward.

46. (d)

47. (c)

Using the momentum equation, the rate of change of horizontal momentum, f_h, is

F_h = ρQ (horizontal velocity in – horizontal velocity out)

$$= \rho Q\,(v_{jet} - v_{jet}\cos 40°)$$

$$F_h = \rho A_{jet} v_{jet}(v_{jet} - v_{jet}\cos 40°)$$

$$= \rho A_{jet} v_{jet}^2 (1 - \cos 40°).$$

48. (c)

Rate of change of linear momentum = force

Rate of change of angular momentum = Torque

49. (d)

50. (b)

For V notch

$$Q = KH^{5/2}$$

$$\Rightarrow dQ = \frac{5}{2}K.H^{3/2}.dH$$

$$\Rightarrow \frac{dQ}{Q} = \frac{5}{2}\frac{dH}{H}$$

$$\Rightarrow \frac{dQ}{Q} = \frac{5}{2}\times\frac{.15}{75}$$

$$\therefore \frac{dQ}{Q}\times 100 = \frac{5}{2}\times\frac{.15}{75}\times 100 = 0.5\%$$

51. (c)

52. (c)

53. (d)

$$R_e = \frac{Vd}{\nu}$$

$$= \frac{0.015\times 0.1}{1.13\times 10^{-6}}$$

$$= 1327.43 \text{ (laminar)}$$

$$f = \frac{64}{R_e} = 0.048$$

54. (d)

Pressure drop across a length L of pipe is

$$\Delta p = \frac{32\mu u_{av} L}{D^2} \quad \text{...(i)}$$

and $u_{av} = \frac{u_0}{2}$ ...(ii)

From equation (i) and (ii)

$$\Delta p = \frac{16\mu u_0 L}{D^2}$$

55. (d)

56. (c)

$$L_r = \frac{L_m}{L_P} = \frac{1}{80}$$

$$Q_m = 2.3 \text{ m}^3\text{/sec}$$

Let discharge of prototype is Q_P

$$\frac{Q_m}{Q_P} = Q_r = L_r^{5/2}$$

$$\frac{Q_m}{Q_P} = \left(\frac{1}{80}\right)^{5/2}$$

$$Q_P = 2.3 \times 80^{5/2}$$

$$Q_P = 131659.7 \text{ m}^3\text{/sec.}$$

$$Q_P = 36.57 \text{ m}^3\text{/hr}$$

57. (a)

For laminar flow between parallel plates, equation of velocity

$$\frac{\partial p}{\partial x} = \mu\frac{\partial^2 v}{\partial y^2}$$

Differential form of Bernoulli's equation is

$$dp + \rho g dz + \rho v dv = 0$$

on integration

$$p + \rho g\cdot z + \rho\frac{v^2}{2} = \text{constant}$$

$$\Rightarrow \frac{p}{\gamma} + z + \frac{v^2}{2g} = \text{constant}$$

58. (d)

Thickness of laminar sub layer

$$\delta' = \frac{11.6\nu}{u_*}$$

where $u_* = u_{avg}\sqrt{\frac{f}{8}}$

$$u_{avg} = \frac{0.1}{\frac{\pi}{4}(0.3)^2} = 1.415 \text{ m/sec}$$

$$f = \frac{0.316}{\left(\frac{1.415\times 0.3}{0.125\times 10^{-4}}\right)^{1/4}} = 0.023$$

$$\delta' = \frac{11.6\times 0.125\times 10^{-4}}{1.415\sqrt{\frac{0.023}{8}}}$$

$$\delta' = 1.89 \times 10^{-3} \text{ m}$$

$$= \mathbf{1.89}.$$

59. (d)

Maximum permissible height of roughness

$$\frac{K}{\delta'} < 0.25$$

$$K = 0.25 \times 1.89 \times 10^{-3} \text{ m}$$
$$K = 0.4725 \times 10^{-3}\text{m}$$
$$= \mathbf{0.4725}.$$

60. (c)

The friction head loss in pipe,

$$h_f = \frac{4fL}{D} \times \frac{V^2}{2g}$$

In turbulent flow, f is constant so $h_f \propto V^2$.

61. (d)

The general expression for non-Newtonian fluid.

$$\tau = \tau_0 + \mu\left(\frac{du}{dy}\right)^x$$

So 'τ' is not linear function of velocity gradient or distance.

This is due to large size of molecules in polymers etc. and do not behave like molecules of Newtonian fluid.

62. (a)

63. (b)

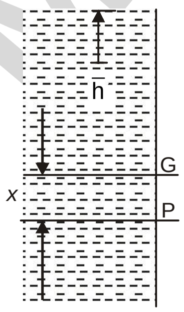
The distance between centre of pressure and centroid of surface

$$x = h - \bar{h}$$

$$\because \quad h = \bar{h} + \frac{I_a}{A\bar{h}}$$

$$\therefore \quad x = \bar{h} + \frac{I_a}{A\bar{h}} - \bar{h}$$

$$= \frac{I_G}{A\bar{h}}$$



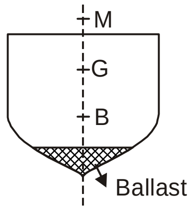
At great depth $\bar{h}$ is very high and the other terms are constant. So the whole term become negligible.

64. (b)

This is the case of floating body. Ballast loading of bottom means addition of heavy weight in lower portion of ship. The ballast increases weight and brings the center of gravity lower. The stability is related to metacentric height,

$$MG = \frac{I}{V} - BG > 0$$

As metacentric height Gm increases, the stability increases.



65. (a)

The time period of transverse oscillation (ie. oscillation about the longitudinal axis) or rolling of a ship or a floating body is given by

$$T = 2\pi\left[\frac{K_G^2}{g\,GM}\right]^{1/2}$$

Where

T = time period of transverse oscillation

K_G = radius of gyration of the floating body about its centre of gravity

$\overline{GM}$ = metacentric height; and

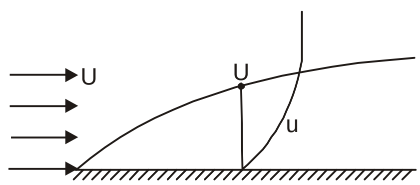
g = acceleration due to gravity

The increasing the metacentric height gives greater stability to a floating body whereas an increase in the metacentric height reduces the time period of rolling of the body. A smaller value of time period of rolling of a passenger ship is quite uncomfortable for the passengers. Further, a ship with a smaller time period of rolling is subjected to undue strains which may damage its structure.

66. (a)

Streamlines are a family of curves that are instantaneously tangent to the velocity vector of the flow. These show the direction a fluid element will travel in at any point in time. By definition, different streamlines at the same instant in a flow do not intersect, because a fluid particle cannot have two different velocities at the same point.

67. (a)



At outer layer of boundary layer, the velocity gradient is zero

$$\therefore \qquad \frac{du}{dy} = 0$$

i.e. at outer edge, u = U

So shear stress from Newton's law of viscosity.

$$\tau = u\frac{du}{dy} = 0$$

68. (c)

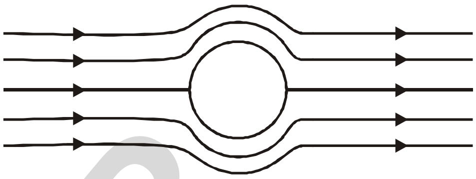
Ideal fluids are those fluids which have no viscosity and surface tension and they are incompressible. As such for ideal fluids no resistance is encountered as the fluid moves.

- A flow is said to be rotational if the fluid particles while moving in the direction of flow rotate about their mass centres. The liquid in the rotating tanks illustrates rotational flow where the velocity of each particle varies directly as the distance from the centre of rotation.

- A flow is said to be irrotational if the fluid particles while moving in the direction of flow do not rotate about their mass centres. It may however be stated that a true irrotational flow exists only in the case of flow of an ideal fluid for which no tangential or shear stresses occur. But the flow of practical fluids, may also be assumed to be irrotational if the viscosity of the fluid has little significance.

69. (d)

70. (a)



The flow is unidirectional and uniform in a rectilinear flow. The flow has no vorticity and thus the velocity field is irrotational. Unlike a real fluid, the net drag on the body is zero.

71. (d)

72. (b)

73. (a)

74. (b)

75. (d)

Both reynolds law & froude law both must be considered.