POSTAL Book Package 2021

Mechanical Engineering

Objective Practice Sets

Fluid Mechanics

Contents

MADE EASY Publications

13 CHAPTER
Dimensional Analysis

Q.1 The geometrical similarity between model and prototype is achieved by
(a) using different model scales for horizontal and vertical dimension
(b) using the same model scale throughout
(c) having the same radius of curvature at identical places in model and prototype
(d) None of these

Q.2 Which one of the following statements is not correct?
(a) Models are always smaller than the prototypes.
(b) Dynamic similarity between a model and a prototype can be verified by equating Reynolds number in a viscous flow.
(c) Mach number achieves significance when the velocity of fluid approaches or exceeds the sonic velocity.
(d) Distorted models are always exaggerated on a vertical scale.

Q.3 **Statement (I):** Reynolds number must be the same for model and the prototype when both are tested as immersed in a subsonic flow.

Statement (II): A model should be geometrically similar to the prototype.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is ***not*** the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

Q.4 Kinematic similarity between model and prototype is the similarity of
(a) shape (b) discharge
(c) stream (d) forces

Q.5 Consider the following statements:
1. Complete similarity between model and prototype envisages geometric and dynamic similarities only.
2. Distorted models are necessary where geometric similarity is not possible due to practical reasons.
3. In testing of model of a ship, the surface tension forces are generally neglected.
4. The scale effect takes care of the effect of dissimilarity between model and prototype.

Which of these statements are correct?
(a) 1 and 3 (b) 1, 2 and 4
(c) 2 and 3 (d) 2 and 4

Q.6 Principles of similitude form the basis of
(a) performing acceptance tests
(b) comparing two identical equipments
(c) comparing similarity between design and actual equipment
(d) design and testing models of prototype based on results of models

Directions : Each of the next items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. Examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true; but Statement (II) is false
(d) Statement (I) is false; but Statement (II) is true

Q.7 **Statement (I) :** In fluid system model studies, a simple scaling-up of measurements made on the model may not yield results accurately corresponding to the prototype.

Statement (II) : Surface tension forces may be relatively much more significant in the model than in the prototype.

Q.8 **Statement (I) :** When both gravitational and viscous forces are predominant in a flow, scale ratio can be chosen at will.

Statement (II) : With both gravitational and viscous forces being predominant, scale ratio depends upon kinematic viscosity of the fluids.

Q.9 It is observed in a flow problem that total pressure, inertia and gravity forces are important. Then, similarity requires that

(a) Reynolds and Weber numbers be equal
(b) Mach and Froude numbers be equal
(c) Euler and Froude numbers be equal
(d) Reynolds and Mach numbers be equal

Q.10 Consider the following statements:

1. For achieving dynamic similarity in model studies on ships, Froude numbers are equated.
2. Reynolds numbers should be equated for studies on aerofoil for dynamic similarity.
3. In model studies on a spillway, the ratio of width to height is equated for kinematic similarity.

Which of these statements are correct?

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

Q.11 Consider the following statements:

1. Mach number represents the ratio of velocity of sound to fluid velocity
2. Weber number represents ratio of inertia force and surface tension force

Of these statements

(a) 1 is correct
(b) 2 is correct
(c) Both 1 and 2 is correct
(d) Neither 1 nor 2

Q.12 Which of the following statements are correct?

1. Depression of mercury in a capillary tube is dependent on density and surface tension.
2. Modelling of flow-induced drag on a ship is done invoking both of Froude number and Reynolds number.
3. Flow of a fluid in a narrow pipe is relatable to both Reynolds number and Cauchy number.
4. Formation and collapse of a soap bubble is analyzed through employing surface tension and external pressure.
5. Flow over the downstream slope of an ogee spillway can be affected by surface tension.

Select the correct answer using the codes given below:

(a) 1, 2 and 4 (b) 1, 3 and 5
(c) 2, 3 and 4 (d) 3, 4 and 5

Q.13 The Buckingham π theorem is widely used in the dimensional analysis and expresses the resulting equation in terms of

(a) geometric, kinematic and dynamic variables
(b) n - dimensionsless variables
(c) $(n - m)$ dimensionless variables
(d) the independent and dependent variables

Q.14 In a fluid machine, the relevant parameters are volume flow rate, density, viscosity, bulk modulus, pressure difference, power consumption, rotational speed and characteristic dimension. Using the Buckingham pi (π) theorem, what would be the number of independent non-dimensional groups?

(a) 3 (b) 4
(c) 5 (d) None of these

Q.15 Consider the following statements:

1. Dimensional analysis is used to determine the number of variables involved in a certain phenomenon.
2. The group of repeating variables in dimensional analysis should include all the fundamental units.
3. Buckingham's π theorem stipulates the number of dimensionless groups for a given phenomenon.
4. The coefficient in Chezy's equation has no dimension.

Which of these statements are correct?

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

Q.16 A model test is to be conducted for an under water structure, which is likely to be exposed to strong water currents. The significant forces are

Q.24 A ship model 1 m long with negligible friction is tested in a towing tank at a speed of 100 cm per second. If the ship length is 64 m, then the corresponding ship velocity will be ________ m/s.

Q.25 A spillway model constructed to a scale of 1 : 4 gives a discharge of 10 m^3/sec. The discharge from the prototype would be ___________ m^3/s.

Q.26 A 1 : 30 model of an ogee spillway crest records an acceleration of 1.3 m/s^2 at a certain location. The homologous value of the acceleration in the prototype in m/s^2, is
(a) 0.043 (b) 0.237
(c) 1.300 (d) 7.120

Q.27 In a laboratory, a flow experiment is performed over a hydraulic structure. The measured values of discharge and velocity are 0.05 m^3/s and 0.25 m/s, respectively. If the full scale structure (30 times bigger) is subjected to a discharge of 270 m^3/s, then the time scale (model to full scale) value (up to two decimal places) is ______

Q.28 An orifice meter to carry water is calibrated with air in a geometrically similar model at 1/6 the prototype scale. Dynamically similar flow will be obtained when the discharge ratio (air to water) is __________. [Assume the ratio kinematic viscosity of air to water as 12.5]

Q.29 In a flow condition where both viscous and gravity forces dominate and both the Froude number and the Reynolds number are the same in model and prototype; and the ratio of kinematic viscosity of model to that of the prototype is 0.0894. What is the model scale?
(a) 1 : 3.3 (b) 3.3 : 1
(c) 5 : 1 (d) 1 : 5

Q.30 A sphere is moving in water with a velocity of 1.6 m/s. Another sphere of twice the diameter is placed in a wind tunnel and tested with air which is 750 times less dense and 60 times less viscous than water. The velocity of air that will give dynamically similar conditions is
(a) 5 m/s (b) 10 m/s
(c) 20 m/s (d) 40 m/s

Q.31 A ship model 1/60 scale with negligible friction is tested in a towing tank at a speed of 0.6 m/s. If a force of 0.5 kg is required to tow the model, the propulsive force required to tow prototype ship will be
(a) 5 MN (b) 3 MN
(c) 1 MN (d) 0.5 MN

Q.32 A 1 : 20 model of a spillway dissipated 0.25 hp. The corresponding prototype horsepower dissipated will, be
(a) 0.25 hp (b) 5.00 hp
(c) 447.20 hp (d) 8944.30 hp

Q.33 The flow of glycerin (kinematic viscosity $\nu = 5 \times 10^{-4}$ m^2/s) in an open channel is to be modeled in a laboratory flume using water ($\nu = 10^{-6}$ m^2/s) as the flowing fluid. If both gravity and viscosity are important, what should be the length scale (i.e., ratio of prototype to model dimensions) for maintaining dynamic similarity?
(a) 1 (b) 22
(c) 63 (d) 500

Q.34 In order to estimate the energy loss in a pipeline of 1 m diameter through which kerosene of specific gravity 0.80 and dynamic viscosity 0.02 poise is to be transported at the rate of 2 m^3/s, model tests were conducted on a 0.1 m diameter pipe using water at 20°C. If the absolute viscosity of water at 20°C is 1.00×10^{-2} poise, then the discharge required for the model pipe would be
(a) 60 *l*/s (b) 80 *l*/s
(c) 120 *l*/s (d) 160 *l*/s

Q.35 A 1 : 25 model of a naval ship is towed at a velocity of 1.2 m/s to determine each of the two components of the total drag that may be experienced by the prototype. The wave-making drag of the model is duly estimated to be 0.37 kgf. What would be the wave making drag on the prototype ship?
(a) 1250 kgf (b) 1875 kgf
(c) 3750 kgf (d) 4625 kgf

Q.36 A 1: 30 scale model of a submarine is to be tested in a wind tunnel for its drag when it is operating at 15 km/h in ocean. The kinematic viscosity of air is 1.51×10^{-5} m^2/s and for water 1.02×10^{-6} m^2/s. What is the velocity of air in

Q.48 An orificemeter to measure water flow is calibrated with air in a geometrically similar model at 1/10 prototype scale. Assume the ratio of kinematic viscosity of air to water as 12. Dynamically similar flow will be obtained when the discharge ratio (air to water) is __________.

Q.49 A river reach of 4 km is modeled in the laboratory where maximum discharge is 0.3 m^3/s. If maximum flood discharge is 3000 m^3/s, then for equality of froude's number, length of river reach in the model will be nearly

(a) 30 m (b) 300 m
(c) 0.15 km (d) 0.1 km

Q.50 A 1 : 6 model automobile tested in a wind tunnel in the same air properties as in prototype. The prototype velocity is 48 kmph for dynamic similar its conditions, the model drag is 320 N, the drag on the protopype is _________ N.

■■■■

Answers — Dimensional Analysis

1. (b)	2. (a)	3. (b)	4. (b)	5. (c)	6. (d)	7. (b)	8. (d)	9. (c)	10. (a)
11. (d)	12. (a)	13. (c)	14. (c)	15. (d)	16. (d)	17. (d)	18. (c)	19. (c)	20. (c)
21. (b)	22. (b)	23. 0.29	24. 8	25. 320	26. (c)	27. 0.1829		28. 2.08	29. (c)
30. (b)	31. (c)	32. (d)	33. (c)	34. (b)	35. (*)	36. (c)	37. (a)	38. (b)	39. (d)
40. (b)	41. (c)	42. (c)	43. 400	44. (c)	45. (b)	46. (b)	47. (a)	48. 1.2	49. (d)
50. 320									

Explanations — Dimensional Analysis

1. (b)

Geometric similarity exists between the model and the prototype if the ratios of corresponding length dimensions in the model and the prototype are equal. Different model scales for horizontal and vertical dimension are used in a distorted model. Geometric similarity is achieved by using same model scale throughout.

2. (a)

Models may be larger than prototypes also. e.g., model of carburettor. However in general models are smaller than the prototypes.

4. (b)

Kinematic similarity: If the ratio of velocity and acceleration at the corresponding points in the model and prototype are same then there exist kinematic similarity.

5. (c)

2nd and 3rd statement are correct, therefore correct option will be (c).

In a general flow field, complete similarity between a model and prototype is achieved only when there is geometric, kinematic and dynamic similarity.

8. (d)

If both viscous and gravity forces are predominant

$$\frac{V_r}{\sqrt{g_r l_r}} = 1$$

$$\therefore \quad V_r = \sqrt{l_r g_r} \quad \text{...(i)}$$

$$\frac{l_r V_r}{\gamma_r} = 1 \quad \text{...(ii)}$$

from eq^n (i) and eq^n (ii)

$$\gamma_r = l_r \cdot \sqrt{l_r} \quad (g_r = 1)$$

$$\gamma_r = l_r^{3/2}$$

$\therefore$ Hence, scale ratio depends upon kinematic viscosity of fluid.

9. (c)

Euler number : $E_u = \left(\frac{\text{inertia force}}{\text{Pressure force}}\right)^{1/2}$

Froude number : $F = \left(\frac{\text{inertia force}}{\text{Gravity force}}\right)^{1/2}$

11. (d)

Mach no. (M) = $\sqrt{\frac{\text{Inertia force}}{\text{Elastic force}}} = \sqrt{\frac{\rho . l^2 V^2}{K . l^2}}$

$= \frac{V}{\sqrt{\frac{K}{\rho}}} = \frac{V}{C}$

$C = \sqrt{\frac{K}{\rho}}$

= Velocity of sound in the medium

Weber no. (W_e) = $\sqrt{\frac{\text{Inertia force}}{\text{Surface tension force}}}$

12. (a)

- Capillary tube depression $h = \frac{2\sigma\cos\theta}{\rho g R}$, dependent on surface tension, density and diameter of tube.
- In modeling of flow induced drag is done invoking both Froude no. and Reynold's no.
- Flow of a fluid in a narrow pipe mainly relatable to Reynold's no. (Cauchy number is square of Mach no. and mainly used for compressible liquids).
- Flow over the downstream slope of an Ogee spillway is affected by Froude no.

13. (c)

Buckingham's π-theorem states that if there are n variables (independent and dependent variables) in a physical phenomenon and if these variables contain m fundamental dimensions (M, L, T), then the variables are arranged into $(n - m)$ dimensionless terms. Each term is called π-term.

14. (c)

No. of variables: $n = 8$
No. of fundamental dimension: $m = 3$
No. of π terms = $n - m = 8 - 3 = \mathbf{5}$

15. (d)

Chezy's constant has dimension $= L^{1/2}T^{-1}$

16. (d)

$Re = \frac{\rho VD}{\mu}$

Froude number $= \frac{V}{\sqrt{gL}}$

17. (d)

Drag force, $F = \phi(V, \rho, U, L, g)$

$$\frac{F}{\rho L^2 V^2} = Q\left(\frac{\rho VL}{\mu}, \frac{V}{\sqrt{gL}}\right) = \phi(Re, Fr)$$

18. (c)

For sphere, $A = \frac{\pi}{4}D^2$

$$F_D = C_D \times \frac{1}{2} \times \rho \times A \times V^2$$

or, $$F_D = C_D \times \frac{1}{2} \times \rho \times \left(\frac{\pi}{4}D^2\right) \times V^2$$

or, $$\frac{F_D}{\rho D^2 V^2} = \frac{1}{2} \times \left(\frac{\pi}{4}\right) \times C_D$$

Hence, right hand side is dimensionless, so $\frac{F_D}{\rho D^2 V^2}$ should also be a dimensionless parameter.

Option (c) $\frac{F_D}{\rho V^2 D^2}, \frac{\rho VD}{\mu}$

19. (c)

Number of variables = 6
Number of fundamental dimensions = 3
∴ Number of dimensionless parameters = 6 − 3 = 3.
Take D, V, and ρ as repeating variables.

$\frac{VD}{\mu}$ will not be dimensionless number as its dimension is $[M^{-1}L^3]$

20. (c)

Discharge ratio, $Q_r = L_r^{2.5}$

Prototype discharge = 1000 m^3/s

Model discharge $= \frac{1000}{(9)^{2.5}} = 4.12\ m^3/s$