



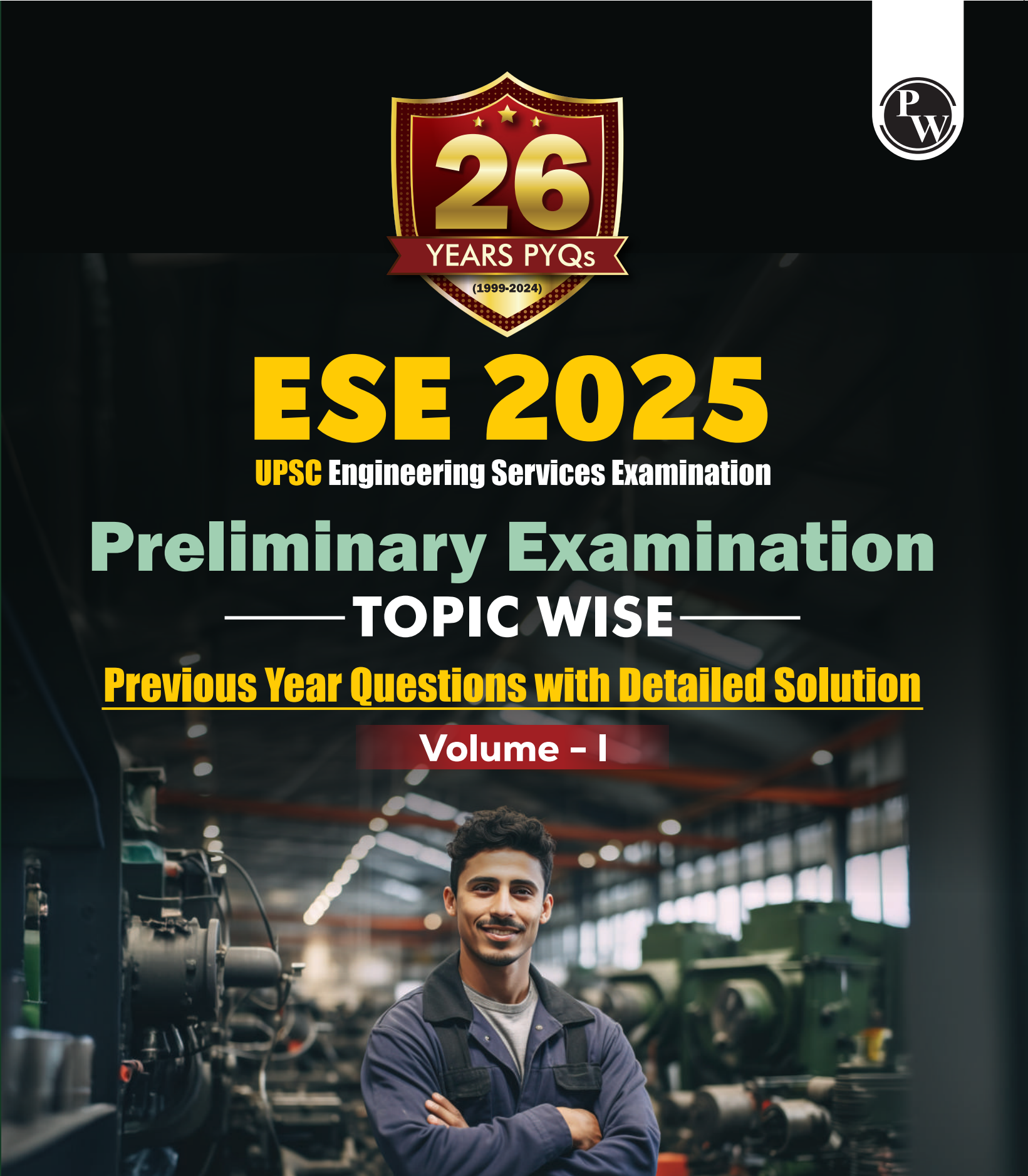
ESE 2025

UPSC Engineering Services Examination

Preliminary Examination —— TOPIC WISE ——

Previous Year Questions with Detailed Solution

Volume - I



MECHANICAL ENGINEERING

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Fluid and its Properties

Viscosity

1. The shear stress developed in a lubricating oil, of viscosity 9.81 poise, filled between two parallel plates 1 cm apart and moving with relative velocity of 2 m/s is [ESE-2001]

- (a) 20 N/m² (c) 196.2 N/m²
(b) 29.62 N/m² (d) 40 N/m²

2. Match List-I (Type of fluid) with List-II (Variation of shear stress) and select the correct answer using the codes given below the lists: [ESE-2002]

List-I

- A. Ideal fluid
B. Newtonian fluid
C. Non-Newtonian fluid
D. Bingham plastic

List-II

1. Shear stress varies linearly with the rate of strain
2. Shear stress does not vary linearly with the rate of strain
3. Fluid behaves like a solid until a minimum yield stress beyond which it exhibits a linear relationship between shear stress and the rate of strain
4. Shear stress is zero

Codes:

- | | A | B | C | D |
|-----|---|---|---|---|
| (a) | 3 | 1 | 2 | 4 |
| (b) | 4 | 2 | 1 | 3 |
| (c) | 3 | 2 | 1 | 4 |
| (d) | 4 | 1 | 2 | 3 |

3. The equation of a velocity distribution over a plate is given by $u = 2y - y^2$, where u is the velocity in m/s at a point y meter from the plate measured perpendicularly. Assuming $\mu = 8.60$ poise, the shear stress at a point 15 cm from the boundary is [ESE-2002]

- (a) 1.72 N/m² (b) 1.46 N/m²
(c) 14.62 N/m² (d) 17.20 N/m²

4. **Assertion (A):** In general, viscosity in liquids increases and in gases it decreases with rise in temperature.

Reason (R): Viscosity is caused by intermolecular forces of cohesion and due to transfer of molecular momentum between fluid layers of which in liquids the former and in gases the later contribute the major part towards viscosity. [ESE-2002]

- (a) Both A and R are individually true and R is the correct explanation of A.
(b) Both A and R are individually true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

5. Match List-I (Rheological equation) with List-II (Types of fluids) and select the correct answer using the codes given below the lists: [ESE-2003]

List-I

- A. $\tau = \mu \left(\frac{du}{dy} \right)^n, n = 1$
B. $\tau = \mu \left(\frac{du}{dy} \right)^n, n < 1$
C. $\tau = \mu \left(\frac{du}{dy} \right)^n, n > 1$
D. $\tau = \tau_0 + \mu \left(\frac{du}{dy} \right)^n, n = 1$

List-II

1. Bingham plastic
2. Dilatant fluid
3. Newtonian fluid
4. Pseudo-plastic fluid

Codes:

- | | A | B | C | D |
|-----|---|---|---|---|
| (a) | 3 | 2 | 4 | 1 |
| (b) | 4 | 1 | 2 | 3 |
| (c) | 3 | 4 | 2 | 1 |
| (d) | 4 | 2 | 1 | 3 |

36. Two horizontal plates are placed 1.25 cm apart, the space between them being filled with an oil of viscosity 15 poises. What is the shear stress in the oil if the upper plate is moved with a velocity of 2.5 m/s?

[ESE-2024]

- (a) 280 N/m² (b) 260 N/m²
(c) 300 N/m² (d) 250 N/m²

37. Consider the following statements:

1. The apparent viscosity of a pseudoplastic fluid decreases with decrease in the shear rate.
2. The apparent viscosity of a dilatant fluid increases with increase in the shear rate.
3. Bingham plastic fluid requires a finite yield stress before beginning to flow.

Which of the above statements are correct?

[ESE-2024]

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

Surface Tension and Capillarity

38. If the surface tension of water-air interface is 0.073 N/m, the gauge pressure inside a rain drop of 1 mm diameter will be

[ESE-1999]

- (a) 0.146 N/m² (b) 73 N/m²
(c) 146 N/m² (d) 292 N/m²

39. A capillary tube is inserted in mercury kept in an open container.

Assertion (A): The mercury level inside the tube shall rise above the level of mercury outside.

Reason (R): The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.

[ESE-2001]

- (a) Both A and R are individually true and R is the correct explanation of A.
(b) Both A and R are individually true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

40. In the phenomenon of cavitation, the characteristic fluid property involved is

[ESE-2002]

- (a) surface tension
(b) viscosity
(c) bulk modulus of elasticity
(d) vapour pressure

41. The capillary rise at 20°C in clean glass tube of 1 mm diameter containing water is approximately

[ESE-2002]

- (a) 15 mm (b) 50 mm
(c) 20 mm (d) 30 mm

42. Consider the following statements:

1. Viscosity
2. Surface tension
3. Capillarity
4. Vapour pressure

Which of the above properties can be attributed to the flow of jet of oil in an unbroken stream?

[ESE-2005]

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

43. A vertical clean glass tube of uniform bore is used as a piezometer to measure the pressure of liquid at a point. The liquid has a specific weight of 15 kN/m³ and a surface tension of 0.06 N/m in contact with air. If for the liquid, the angle of contact with glass is zero and the capillary rise in the tube is not to exceed 2 mm, what is the required minimum diameter of the tube?

[ESE-2006]

- (a) 6 mm (b) 8 mm
(c) 10 mm (d) 12 mm

44. When the pressure on a given mass of liquid is increased from 3.0 MPa to 3.5 MPa, the density of the liquid increases from 500 kg/m³ to 501 kg/m³. What is the average value of bulk modulus of liquid over the given pressure range?

[ESE-2006]

- (a) 700 MPa (b) 600 MPa
(c) 500 MPa (d) 250 MPa

45. What is the pressure difference between inside and outside of a droplet of water?

[ESE-2008]

- (a) $\frac{2\sigma}{d}$ (b) $\frac{4\sigma}{d}$
(c) $\frac{8\sigma}{d}$ (d) $\frac{12\sigma}{d}$

where σ is surface tension and d is the diameter of the droplet.

46. What is the pressure inside a soap bubble, over the atmospheric pressure if its diameter is 2 cm and the surface tension is 0.1 N/m?

[ESE-2008]

- (a) 0.4 N/m² (b) 4.0 N/m²
(c) 40.0 N/m² (d) 400.0 N/m²



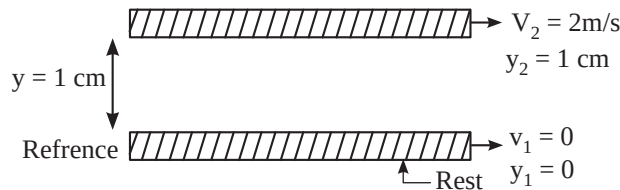
ANSWER KEY

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



SOLUTIONS

1. (b)

Given: $\mu = 9.81$ poiseWe know $1 \text{ poise} = 0.1 \text{ N-s/m}^2$ $\mu = 0.981 \text{ N-s/m}^2$ $y = 1 \text{ cm}$ 

By Newton's law of viscosity

$$\tau = \mu \frac{du}{dy} = \tau = \frac{\mu(v_2 - v_1)}{(y_2 - y_1)}$$

$$\tau = 0.981 \frac{(2 - 0)}{0.01} = 196.2 \text{ N/m}^2$$

2. (d)

For ideal fluid viscosity is zero, so shear stress is also zero (A-4)

For Newtonian fluid

$$\tau = \mu \frac{du}{dy}$$

{Shear stress varies linearly with the rate of strain (B-1)}

For non-Newtonian fluid

$$\tau = A \left(\frac{du}{dy} \right)^n + B$$

So shear stress does not vary linearly with rate of strain.

Hence (C-2)

For Bingham plastic

 $B \neq 0 \quad n = 1$

$$\tau = A \left(\frac{du}{dy} \right) + B$$

So, Bingham plastic behaves like solid until a minimum yield stress beyond which shear stress varies linearly with rate of strain (D-3)

3. (b)

Given :

$$u = 2y - y^2$$

$$\mu = 8.60 \text{ poise} = 0.860 \text{ N-s/m}^2$$

$$u = 2y - y^2$$

$$\frac{du}{dy} = 2 - 2y$$

$$\left. \frac{du}{dy} \right|_{y=0.15\text{m}} = 1.7$$

We known

$$\tau|_{y=0.15\text{m}} = \mu \left. \frac{du}{dy} \right|_{y=0.15\text{m}}$$

$$= 0.86 \times 1.7 = 1.46 \text{ N/m}^2$$

4. (d)

Viscosity is primarily due to cohesion and molecular momentum exchanges between fluid layers.

In case of liquid "as temperature increases cohesive forces decrease, therefore viscosity decrease with increase in temperature"

In case of gases "as temperature increase molecular disturbance also increased. Hence resistance in flow increases. Therefore gases viscosity increases with increases in temperature.



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Volume - II



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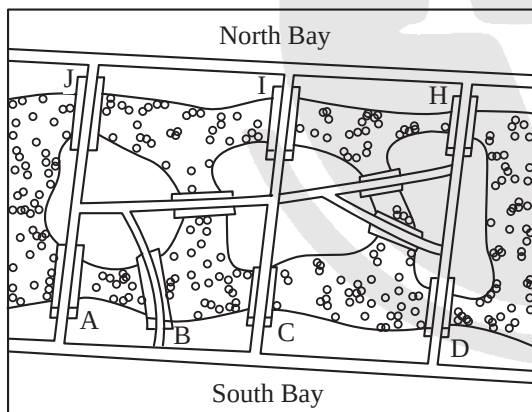
Quantitative Aptitude

Data Interpretation

1. Three hundred passengers are travelling in white, silver and black cars; each of these cars is carrying 6, 5 and 3 passengers, respectively. If the number of white and silver cars is equal and there is only one black car, what is the total number of cars? [ESE-2017]

(a) 52 (b) 53
(c) 54 (d) 55

2. The following map shows the 10 bridges and 3 islands between the suburbs of North Bay and South Bay. During your morning workout, you decide to jog over each bridge exactly once. Which one of the following statements is correct? [ESE-2024]



- (a) You want to start from North Bay and that your workout concludes after you jog over the 'D' bridge.
(b) You want to start from North Bay and that your workout concludes after you jog over the 'E' bridge.
(c) You want to start from North Bay and that your workout concludes after you jog over the bridge.
(d) You want to start from North Bay and that your workout concludes after you jog over the 'G' bridge.
3. Fifty people were asked to rank their preferences of five varieties of chocolate candy, using 1 for their favorite and 5 for their least favorite. The results are shown in the table below.

	Rankings					
Caramel center	5	4	4	4	2	4
Vanilla center	1	5	5	5	5	5
Almond center	4	1	1	3	4	2
Solid chocolate	3	2	3	2	1	1
Number of voters	17	11	9	8	3	2

According to the table (see the column in grey), three voters ranked solid chocolate first, caramel centers second, almond centers third, toffee centers fourth, and vanilla centers fifth. According to this table, which variety of candy would win the taste test using the plurality voting system? [ESE-2024]

- (a) Almond centers
(b) Vanilla centers
(c) Toffee centers
(d) Caramel centers
4. The members of a club are going to elect a president from four nominees. In each first-place vote receives 4 points, each second-place vote receives 3 points, each third-place vote receives 2 points, and each last place vote receives 1 point. If the 100 members of the club mark their ballots as shown in the table below, who will be elected president? [ESE-2024]

	Rankings					
Avalon	2	2	2	2	3	2
Branson	1	4	4	4	2	1
Columbus	3	3	1	3	1	3
Dunkirk	4	1	3	1	4	4
Number of voters	30	24	18	12	10	6

- (a) Avalon
(b) Branson
(c) Columbus
(d) Dunkirk

Numerical Computation

5. Rajiv spends 40% of his salary on food, 20% on house rent, 10% on entertainment and 10% on conveyance. If his savings at the month end are ₹ 2,000, then his monthly salary is [ESE-2017]

(a) ₹ 6,000
(b) ₹ 8,000
(c) ₹ 10,000
(d) ₹ 12,000

6. A total of 324 notes comprising of ₹ 20 and ₹ 50 denominations make a sum of ₹ 12,450. The number of ₹ 20 notes is [ESE-2017]

(a) 200 (b) 144
(c) 125 (d) 110

7. Five Men can paint a building in 20 days, 8 Women can paint the same building in 25 days and 10 Boys can paint it in 30 days. If a team has 2 Men, 6 Women and 5 Boys, how long will it take to paint the building? [ESE-2017]

(a) 12 days
(b) 13 days
(c) 14 days
(d) 15 days

8. A group of workers estimate to finish a work in 10 days, but 5 workers could not join the work. If the rest of them finished the work in 12 days, the number of members present in the team originally is [ESE-2017]

(a) 50 (b) 45
(c) 35 (d) 30

9. A small production unit now works 6 days per week with

$3\frac{1}{3}$ hours of first shift every one of the 6 days and 3

hours of second shift for each of the first 5 days. Wage negotiations led to an agreement to work on 5 days a

week with both shifts together clocking $7\frac{1}{2}$ hours per

day with an 8% increase in weekly wages. How much change in the hourly production would mean parity in the agreement for both management and employees?

[ESE-2018]

(a) 3.68%
(b) 2.15%
(c) 1.82%
(d) 1.33%

10. Let the sum of the squares of successive integers 0, 1, 2, ..., n - 1, n be denoted by S. Let the sum of the cubes of the same integers be denoted by C. It is desirable that

$\frac{C}{S}$, as n increases in steps of 'unity' from 'zero', is given

by the series: $\frac{0}{1}, \frac{3}{3}, \frac{9}{5}, \frac{18}{7}, \frac{30}{9}, \dots$ (for n = 0, 1, 2, 3, 4, ...).

What will this ratio be for n = 8? [ESE-2018]

(a) $\frac{108}{17}$ (b) $\frac{103}{17}$
(c) $\frac{103}{15}$ (d) $\frac{100}{15}$

11. Given that 0.8 is one root of the equation

$x^3 - 0.6x^2 - 1.84x + 1344 = 0$. The other roots of the equations will be- [ESE-2018]

(a) 1.1 and -1.4 (b) -1.2 and 1.4
(c) 1.2 and -1.4 (d) -1.1 and 1.4

12. The equation, $x^3 - 8x^2 + 37x - 50 = 0$ is factored and it has $(3 + 4i)$ as one of its roots. What is the real roots of this equation? [ESE-2018]

(a) 2 (b) 4
(c) 6.5 (d) 13

13. What is the form of the function $f(x)$ for the following data? [ESE-2018]

x	0	1	2	3
f(x)	3	6	11	18

(a) $x^2 + 2x + 3$ (b) $x^2 - 2x + 3$
(c) $x^2 + 2x - 3$ (d) $x^2 - 2x - 3$

14. What is the maximum value of z, if $z = 10x + 6y$ subject to the constraints [ESE-2018]

$3x + y \leq 12, 2x + 5y \leq 34, x \geq 0, y \geq 0$

(a) 56 (b) 52
(c) 52 (d) 40

15. The objective function $z = 3x_1 + 5x_2$ is to be maximized subjected to constraints. [ESE-2018]

$x_1 + 2x_2 \leq 200$

$x_1 + x_2 \leq 150$

$x_1, x_2 \geq 0$

The values of x_1 and x_2 in this context are, respectively

(a) 100 and 75 (b) 125 and 75
(c) 100 and 50 (d) 125 and 50

ANSWER KEY

- | | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (d) | 2. (b) | 3. (c) | 4. (b) | 5. (c) | 6. (c) | 7. (d) | 8. (d) | 9. (a) | 10. (a) |
| 11. (c) | 12. (a) | 13. (a) | 14. (a) | 15. (c) | 16. (c) | 17. (c) | 18. (b) | 19. (a) | 20. (a) |
| 21. (c) | 22. (b) | 23. (c) | 24. (b) | 25. (a) | 26. (a) | 27. (b) | 28. (c) | 29. (a) | 30. (d) |
| 31. (b) | 32. (b) | 33. (b) | 34. (c) | 35. (d) | 36. (c) | 37. (a) | 38. (b) | 39. (b) | 40. (b) |
| 41. (b) | 42. (a) | 43. (c) | 44. (d) | 45. (a) | 46. (c) | 47. (a) | 48. (a) | 49. (d) | 50. (b) |
| 51. (b) | 52. (d) | 53. (b) | 54. (c) | 55. (d) | 56. (a) | 57. (b) | | | |

SOLUTIONS

1. (d)

Given,

Total passengers = 300

and white, silver & Black car carrying 6, 5 & 3 passengers respectively.

Let, no. of white cars be x , so no. of Silver cars is also x .

now, Total passenger will be

$$6x + 5x + (3 \times 1) = 300$$

$$\Rightarrow 11x = 297$$

$$\Rightarrow x = 27$$

So, Total no. of cars = $x + x + 1$

$$\Rightarrow 27 + 27 + 1$$

$$\Rightarrow 55$$

2. (b)

H to G to E to J to A to B to F to C to D to E

3. (c)

Caramel Center (1) Rank = 0

Vanilla Center (1) Rank = 17

Almond Center (1) Rank = 8

Toffee center (1) Rank = $11 + 9 = 20$

Solid Chocolate (1) Rank = $3 + 2 = 5$

4. (b)

Avalon $\rightarrow 180 + 30 = 210$

Branson $\rightarrow 30 + 216 + 26 = 272$

Column bus $\rightarrow 244$

Dunkirk $\rightarrow 225$

5. (c)

Total expenditure = $40\% + 20\% + 10\% + 10\% = 80\%$

$\therefore$ Savings = $(100 - 80) = 20\%$

Thus 20% of income = 2,000

$$\text{Income} = 2,000 \times \frac{100}{20} = 10,000$$

6. (c)

If we consider all 324 notes to be of ₹ 50, then

$$\text{Amount} = 324 \times 50 = 16200$$

But Amount given = 12450

$$\text{Difference} = (16200 - 12450) = 3750$$

The difference of ₹ 30 gives ₹ 20 notes every time

$$\therefore \text{₹ 20 notes} = \frac{3750}{30} = 125$$

OR

₹ 20 notes = T ; ₹ 50 notes = F

$$T + F = 324$$

$$20T + 50F = 12450$$

$$50T + 50F = 16200 \quad (324 \times 50)$$

$$\begin{array}{r} - \quad + \quad - \\ \hline -30T = -3750 \end{array}$$

$$T = \frac{3750}{30} = 125$$

7. (d)

$$5 \text{ Men per day} = \frac{1}{20}$$

$$\therefore 1 \text{ Man} = \frac{1}{20 \times 5} = \frac{1}{100}$$



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$$G = 6.67 \times 10^{-11} (N \cdot m^2 / kg^2)$$
$$g = 9.8 \, m/s^2$$

$$F = \frac{G m_1 m_2}{r^2}$$

$$T = 2\pi \sqrt{\frac{m}{k}}$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$$W = \int p \, dV$$

$$(x^h) = m x^{h-1} a b^2$$
$$a^2 \sqrt{b^2 + c^2}$$

$$(x^h) = h x^{h-1}$$
$$4x^2 + y + ab$$
$$x = a^2 + b^2$$

$$\sqrt{\sum (x_i - y_i)^2}$$

$$a = \frac{\Delta v}{\Delta t}$$

$$v = v_0 + at$$
$$w = w_0 + at$$



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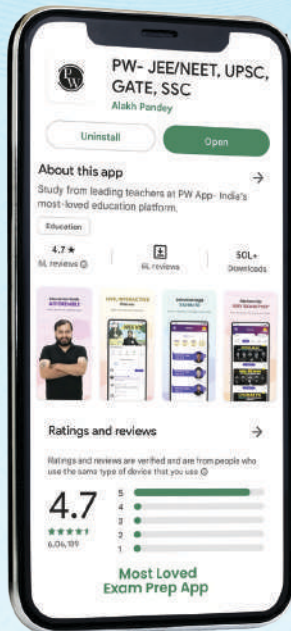
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