Read the following instructions carefully.

1. All questions in this paper are of objective type.
2. There are a total of 65 questions carrying 100 marks.
3. Questions 1 to 25 will carry 1 mark each and questions 26 to 55 will carry 2 marks each.
4. Questions 48 to 51 (2 pairs) are common data questions and questions 52 to 55 (2 pairs) are linked answer questions. The answer to the second question of the linked answer questions depends on the answer to the first question of the pair. If the first question in the linked pair is wrongly answered or is unattempted, then the answer to the second question in the pair will not be evaluated.
5. Questions 56 to 65 belong to General Aptitude (GA). Questions 56 to 60 will carry 1 mark each and questions 61 to 65 will carry 2 marks each.
6. Unattempted questions will carry zero marks.
7. Wrong answers will carry negative marks. For Q.1–Q.25 and Q.56–Q.60, $\frac{1}{3}$ mark will be deducted for each wrong answer. For Q.26–Q.51 and Q.61–Q.65, $\frac{2}{3}$ mark will be deducted for each wrong answer. The question pairs (Q.52, Q.53), and (Q.54, Q.55) are questions with linked answers. There will be negative marks only for wrong answer to the first question of the linked answer question pair *i.e.*, for Q.52 and Q.54, $\frac{2}{3}$ mark will be deducted for each wrong answer. There is no negative marking for Q.53 and Q.55.

(1 Mark Questions)

1. For ideal ramjet engine, the exit Mach number is
(a) less than incoming Mach number
(b) equal to incoming Mach number
(c) greater than incoming Mach number
(d) depends on freestream conditions and fuel burn rate

2. Following are the Reynolds decomposition for turbulent flow into mean and fluctuating velocity components. Which of the following statements holds true?
(a) Both mean and fluctuating components independently satisfy continuity equation
(b) Mean velocity components satisfy continuity equation but fluctuating components don't satisfy
(c) Mean flow does not satisfy continuity but the fluctuating components do so
(d) Neither the mean nor the fluctuating velocity components can satisfy continuity equation independently, only the instantaneous velocity components which is the sum of both satisfy the continuity equation

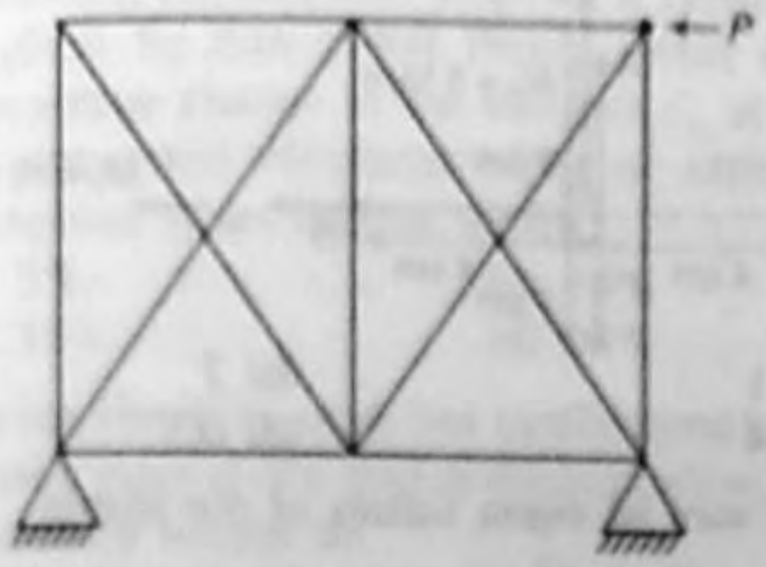
3. Which of the following functions is not periodic?
(a) $\sin x^2$ (b) $e^{\cos x}$
(c) $\ln (1 + \sin^2 2x)$ (d) Constant

4. Consider $f(x) = \begin{cases} e^x & ; \quad x > 0 \\ 1 & ; \quad x = 0 \\ \cos x & ; \quad x < 0 \end{cases}$
The above function is
(a) continuous and differentiable at $x = 0$
(b) continuous but not differentiable at $x = 0$
(c) differentiable but not continuous at $x = 0$
(d) neither differentiable nor continuous at $x = 0$

5. Which of the following is the right combination for a typical passenger aircraft to have a stable trim flight?
(a) $C_{m_0} > 0$ and $C_{m_\alpha} > 0$
(b) $C_{m_0} > 0$ and $C_{m_\alpha} < 0$
(c) $C_{m_0} < 0$ and $C_{m_\alpha} > 0$
(d) $C_{m_0} < 0$ and $C_{m_\alpha} < 0$

6. In a standard altimeter used in aircraft, which of the following quantities is measured to determine the altitude of airplane?
(a) Static pressure (b) Stagnation pressure
(c) Static temperature (d) Air density

7. In a phugoid manoeuvre, which of the following remains almost constant?
(a) Angle of attack (b) Altitude
(c) Aircraft speed (d) Pitch angle

8. 

The degree of redundancy in above structure is
(a) 1 (b) 2
(c) 3 (d) 4

9. Due to presence of taper in the structure of aircraft wing, which of the following remains unchanged compared to the case with no taper and same applied loads?
(a) Axial stress in longitudinals
(b) Shear flow due to applied bending moment
(c) Shear flow due to torsional moment applied
(d) None of the above

10. The Mach number at the inlet of a nozzle is 1.1. The shape of nozzle should be
(a) converging (b) diverging
(c) converging-diverging (d) diverging-converging

11. Stokes theorem connects
(a) a line integral and surface integral
(b) a surface integral and volume integral
(c) a line integral and volume integral
(d) gradient of a function and its surface integral

12. A fluid flow is represented by velocity field $\vec{v} = ax\,\hat{i} + ay\,\hat{j}$, where a is a constant. The equation of streamline passing through a point (2, 1) is
(a) $x - 2y = 0$ (b) $2x - y = 0$
(c) $2x + y = 0$ (d) $x + 2y = 0$

13. For a fluid flow through a convergent pipe of length L having inlet radius R_1 and outlet radius R_2 and constant flow rate Q; the acceleration at the exit assuming velocity to be axial and uniform at any cross-section, is
(a) $\dfrac{2Q^2(R_1 - R_2)}{\pi R_2^5 L}$ (b) $\dfrac{2\pi^2 Q^2(R_1 - R_2)}{R_1^5 L}$
(c) $\dfrac{2Q^2(R_1 - R_2)}{\pi^2 R_2^5 L}$ (d) $\dfrac{2Q^2(R_1 - R_2)}{\pi^2 R_1^5 L}$

14. In a spring-mass system, the mass is 0.1 kg and stiffness of the spring is 1 kN/m. By introducing a damper the frequency of oscillation becomes 90% of the original value. What is the damping coefficient of the system?
(a) 1.2 N-s/m (b) 3.4 N-s/m
(c) 8.7 N-s/m (d) 12 N-s/m

15. Across a normal shock, which of the following quantities remains unchanged?
(a) Stagnation temperature (b) Static temperature
(c) Stagnation pressure (d) Stagnation density

16. Starting from $x_0 = 1$, one step of Newton-Raphson method in solving the equation $x^3 + 3x - 7 = 0$ gives the next value (x_1) as
(a) 0.5 (b) 1.406
(c) 1.5 (d) 2

17. Total number of independent variables in the linear stress-strain relationship of an isotropic material is
(a) 1 (b) 2
(c) 3 (d) 4

18. To minimize power requirement of an aircraft, which of the following should be minimized?
(a) $\dfrac{C_L}{C_D}$ (b) $\dfrac{C_D}{C_L}$
(c) $\dfrac{C_D}{\sqrt{C_L}}$ (d) $\dfrac{C_D}{C_L^{3/2}}$

19. Which of the following tends to impart rolling stability to an aircraft?
(a) Anhedral
(b) Wings positioned at top of fuselage
(c) Swept forward wing
(d) None of the above

20. Euler's equation is valid for
(a) inviscid incompressible flow only
(b) compressible as well as incompressible inviscid flow
(c) viscous or inviscid incompressible flow
(d) potential flow only

21. A body travelling in a hyperbolic orbit around a planet will have
(a) zero speed at infinite distance from planet
(b) finite speed at infinite distance from planet
(c) infinite speed at infinite distance from planet
(d) will always be at finite distance from planet

22. If ψ is the stream function and (r, θ) are the polar coordinates, which of the following gives the radial and tangential velocity components?
(a) $v_r = \dfrac{1}{r}\dfrac{\partial \psi}{\partial \theta}$, $v_\theta = \dfrac{-\partial \psi}{\partial r}$
(b) $v_r = \dfrac{1}{r}\dfrac{\partial \psi}{\partial \theta}$, $v_\theta = \dfrac{\partial \psi}{\partial r}$
(c) $v_r = \dfrac{-1}{r}\dfrac{\partial \psi}{\partial \theta}$, $v_\theta = \dfrac{\partial \psi}{\partial r}$
(d) $v_r = \dfrac{\partial \psi}{\partial r}$, $v_\theta = \dfrac{-1}{r}\dfrac{\partial \psi}{\partial \theta}$

23. Which of the following remains constant across a centrifugal compressor?

(a) Total enthalpy (b) Total pressure

(c) Rothalpy (d) Static enthalpy

24. Consider a slender straight column of length 1m which is built-in at one end and the other end is free. Given, $EI = 4 \times 10^6$ N-m^2, the buckling load for the column is approximately

(a) 2.5 MN (b) 10 MN

(c) 40 MN (d) 20 MN

25. For maximum range of gliding flight, which of the following holds true?

(a) $C_{D_0} = KC_L^2$ (b) $C_{D_0} = 3K\,C_L^2$

(c) $C_{D_0} = \dfrac{K\,C_L^2}{3}$ (d) $C_{D_0} = KC_L^2/2$

where, $K = \dfrac{1}{\pi\, eAR}$

(2 Marks Questions)

26. Which of the following PDEs in $u(x, y)$ is parabolic?

(a) $u_{XX} + 2u_X - 3u_Y + u_{YY} - 2u_{XY} = 37$

(b) $4u_{XX} - 4u_{XY} + u_{YY} - 54 = 0$

(c) $9u_{XX} - 7u_X - 6u_{XY} + 8u_Y + 4u_{YY} - 76 = 0$

(d) None of the above

27. In a coordinated horizontal turn, the load factor was 2. What will be the load factor, if for the same manoeuvre at same turn rate, the speed becomes twice?

(a) 4 (b) 1

(c) 3.6 (d) 5

28. Consider an ideal axial turbine in which air enters at total temperature 700 K and leaves at axial speed 300 m/s and temperature 300 K. The work extracted per unit mass flow rate is

(a) 357 kJ/kg (b) 447 kJ/kg

(c) 960 kJ/kg (d) 492 kJ/kg

$(C_p)_{air} = 1.005$ kJ/kg-K

29. Consider $f(x) = x^3 - 3x^2 - 45x + 24$, the above function

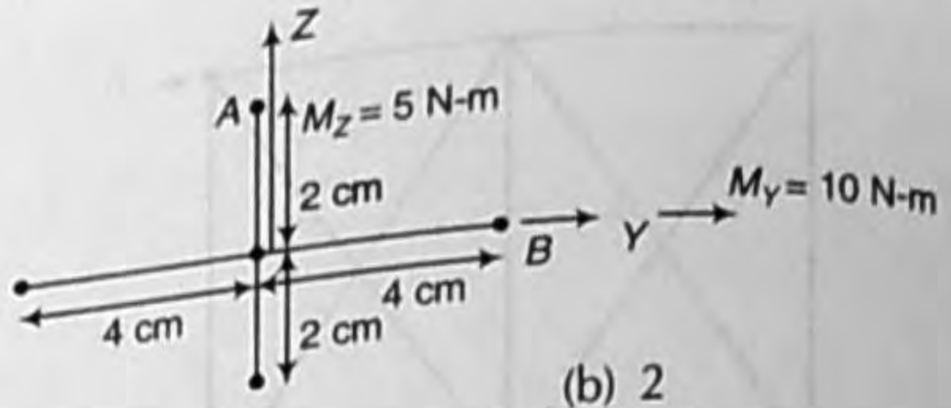
(a) has a maximum at $x = 5$

(b) is increasing in the interval $(-3, 0)$

(c) has a minimum at $x = -3$

(d) is decreasing in the interval $(1, 2)$

30. In the idealized thin-walled tram structure having 5 identical booms and bending moments acting as shown, the ratio of normal stress in boom A to boom B is



(a) 1 (b) 2

(c) 4 (d) 0.5

31. The sum of eigen values of the matrix

$$\begin{bmatrix} 1 & 3 & -1 \\ 5 & 2 & 4 \\ -2 & 4 & 0 \end{bmatrix}$$ is

(a) 3 (b) -31

(c) 32 (d) 64

32. $2x - y + z = 6$

$x - 3y - 2z = -4$

$x - 8y - 7z = -18$

The above system of equations have

(a) no solution (b) unique solution

(c) three solutions (d) infinite solution

33. A satellite is orbiting the earth in an elliptical orbit of eccentricity e and maximum distance from centre of earth a and gravitational potential $\mu = GM$. What is the impulsive force required at the apogee to convert it to a circular orbit

(a) $m\sqrt{\dfrac{\mu}{a}}\left(1+\sqrt{\dfrac{1-e}{1+e}}\right)$ (b) $m\sqrt{\dfrac{\mu}{a}}\left(1-\sqrt{\dfrac{1-e}{1+e}}\right)$

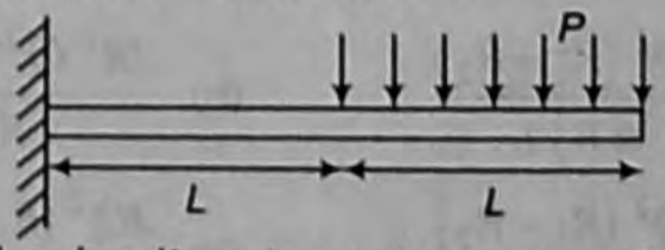
(c) $m\sqrt{\dfrac{\mu}{a}}\left(1+\sqrt{\dfrac{1+e}{1-e}}\right)$ (d) $m\sqrt{\dfrac{\mu}{a}}\left(\sqrt{\dfrac{1+e}{1-e}}-1\right)$

34. An aircraft of weight 1500 kg has an excess power of 300 kW, when flying at a speed of 100 m/s. At the same speed, what is the maximum acceleration it can attain while simultaneous having a climb rate of 10 m/s? (Take $g = 10$ m/s^2)

(a) 0.5 m/s^2 (b) 1 m/s^2

(c) 2 m/s^2 (d) 3 m/s^2

35. Consider a built-in beam of length $2L$ having loading distribution as shown below.



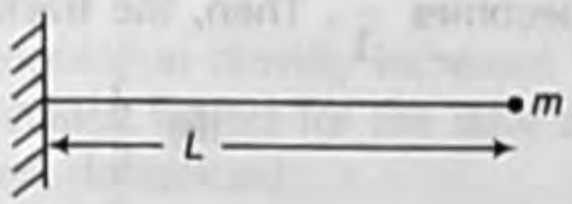
P is the loading intensity per unit length. The maximum bending moment in any cross-section is

(a) $\dfrac{PL^2}{2}$ (b) PL^2

(c) $\dfrac{3PL^2}{2}$ (d) $2PL^2$

36. Assuming the lift-curve slope of a symmetric airfoil is given by thin airfoil theory, what will be the percentage change in the value of C_L at $\alpha = 6°$ for an untwisted elliptical wing of aspect ratio 8 compared to an infinite wing?
(a) 5% (b) 10%
(c) 15% (d) 20%

37. For the vibrations mass less cantilevered beam having a point mass at one end as shown below, the natural frequency would be



(a) $\sqrt{\frac{EI}{mL^3}}$ (b) $\sqrt{\frac{2EI}{mL^3}}$
(c) $\sqrt{\frac{3EI}{mL^3}}$ (d) $\sqrt{\frac{EI}{2mL^3}}$

38. A rocket having specific thrust 200 s is flying at a speed of 800 m/s. In a time when its weight becomes half, what will be its velocity? Neglect any drag or gravitational field.
(a) 1600 m/s (b) 1738.6 m/s
(c) 2158.6 m/s (d) 1358.6 m/s

39. Consider a linear spring-mass system having damping ratio 0.02. What is the fractional loss in total energy per cycle?
(a) 0.0004 (b) 0.98
(c) 0.78 (d) 0.22

40. For a damped oscillator, the value of logarithmic decrement is 5. If the value of damping ratio becomes half, what will be new value of logarithmic decrement?
(a) 2.5 (b) 10
(c) 4.27 (d) 2.06

41. Consider an ideal ramjet flying at a Mach 1.2 at ambient temperature 250 K. The exhaust gases are optimally expanded and leave the engine at a temperature of 1000 K. Assuming the specific heat ratio constant, what is the specific thrust obtained by the engine? (R_{air} = 287 J/kg-K).
(a) 760.6 (b) 380.3 N-s/kg
(c) 633.9 N-s/kg (d) 253.6 N-s/kg

42. An aircraft flying at 100 m/s pitches at the rate 4 deg/s. The horizontal tail having lift-curve slope 4 is located 5 m behind the CG. Assuming tail efficiency factor 1 and taking tail volume coefficient 0.6, the change in pitching moment coefficient felt due to tail effect will be
(a) 0.48 (b) 1.33
(c) 0.0084 (d) 0.023

43. The escape velocity on earth's surface is v_e. The escape velocity on a planet having mass 4 times that of earth and diameter 16 times would be
(a) $\frac{v_e}{4}$ (b) $\frac{v_e}{2}$
(c) v_e (d) $4\,v_e$

44. Water flows over a flat plate in a water tunnel at incoming freestream velocity 10 m/s. The thickness of boundary layer on the plate at a distance 2 m will be
(a) 0.4 mm (b) 0.8 mm
(c) 2 mm (d) 4 mm
Take kinematic viscosity of water as 8.0×10^7 m²/s.

45. The percentage error in approximating the integral $\int_{-1}^{1}(x-x^2)\,dx$ and using Simpson's rule is approximately
(a) zero (b) 5%
(c) 7.5% (d) 10%

46. The value of pressure coefficient at a point on the surface of airfoil at incoming Mach number 0.5 is 8.4. The value of pressure coefficient of the same point at freestream Mach number 0.7 would be
(a) 0.29 (b) 0.56
(c) 0.485 (d) 0.33

47. A turbojet engine is flying at velocity 225 m/s, at an altitude where ambient temperature is 20°C. The stagnation pressure ratio across its diffuser is 0.9. The difuser efficiency is
(a) 0.09 (b) 0.63
(c) 0.97 (d) 0.69
Take R = 287 J/kg-K.

Common Data for Questions 48 and 49
The state of plane stress of point in an isotropic material is given by

$$[\sigma] = \begin{bmatrix} 16 & 5 \\ 5 & -4 \end{bmatrix} \text{ MPa}$$

48. The inclination of plane of zero shear stress w.r.t. specified plane is
(a) 31.7° (b) 26.6°
(c) 13.3° (d) 63.4°

49. The value of minimum shear stress for any rotation of axis is
(a) −6 MPa (b) 10 MPa
(c) 11.2 MPa (d) −11.2 MPa

Common Data for Questions 50 and 51
Fully developed laminar flow of water is established in a circular duct of diameter 30 cm. A hot wire anemometer placed at a distance 10 cm from the centreline reads the flow velocity as 50 cm/s.

50. Volumetric flow rate of water is approximately
(a) 0.06 m^3/s (b) 0.03 m^3/s
(c) 0.04 m^3/s (d) 0.08 m^3/s

51. The shear stress at the wall would be
(a) 10.68 MPa (b) 5.34 MPa
(c) 3.33 MPa (d) 6.68 MPa
Take $\mu_{H_2O} = 8.9 \times 10^{-4}$ Pa-s.

Statements for Linked Answer Questions 52 and 53

An airplane flying straight and level at a speed of 130 m/s at height 10 km is disturbed by a symmetric vertical just resulting in a phugoid oscillation.

52. The approximate frequency of phugoid oscillation is
(a) 0.075 s^{-1} (b) 0.15 s^{-1}
(c) 0.053 s^{-1} (d) 0.107 s^{-1}

53. If $X_v/m = -0.0446\ s^{-1}$ for the airplane, what is the damping ratio of phugoid oscillation?
(a) 0.84 (b) 0.42
(c) 0.21 (d) 0.32

Statements for Linked Answer Questions 54 and 55

A multistage axial compressor operating at an overall adiabatic efficiency of 0.9 develops a total pressure ratio of 10. The total temperature at inlet is 330 K and stagnation enthalpy rise across each stage is 31.5 kJ/kg. Take $\gamma = 1.4$, $C_p = 1.005$ kJ/kg-K.

54. What is the polytropic efficiency for each stage?
(a) 0.89 (b) 0.091
(c) 0.93 (d) 0.95

55. The number of stages required are
(a) 8 (b) 9
(c) 10 (d) 11

General Aptitude

56. Printer *A* can complete 50 pages in 12 min. Printer *B* can print the same manuscript in 30 min. In how many minutes will it take for both printers to print a 100 pages manuscript?
(a) $17\frac{1}{7}$ (b) $20\frac{1}{7}$
(c) 24 (d) 42

57. The areas of two squares are in the ratio 3 : 1, what is the ratio for their perimeters?
(a) 3 : 1 (b) 1 : $\sqrt{3}$
(c) $\sqrt{3}$: 1 (d) 1 : 3

58. The average weight of 24 students in a class is 40 kg. If the weight of the teacher is included, the weight is increased by 500 g. The weight of the teacher is
(a) 52 kg (b) 52.5 kg
(c) 69 kg (d) 53.3 kg

59. A man wishes to divide his monthly savings of ₹ 846 between his two sons and one daughter in the ratio $\frac{1}{4} : \frac{1}{5} : \frac{1}{3}$ respectively. How much did his daughter get?
(a) 270 (b) 216
(c) 360 (d) 300

60. In a fraction, the numerator 8 is less than the denominator. If 3 is added to the numerator, the fraction becomes $\frac{2}{3}$. Then, the fraction is
(a) $\frac{7}{15}$ (b) $\frac{2}{5}$
(c) $\frac{3}{11}$ (d) $\frac{7}{16}$

61. A colony of bacteria in a container grows by each bacterium splitting into eight next generation bacteria. However, because of environmental conditions only 50% of the bacteria in a generation can split as above. A colony of first generation was put in container and it was found that the number of seventh generation bacteria was 4096 million. What was the size of the first generation population initially put in the container?
(a) 2 million (b) 8 million
(c) 1 million (d) 4 million

62. In a nuts and bolts factory, one machine produces only nuts at the rate of 100 nuts per minute and needs to be cleaned for 5 min after production of every 1000 nuts. Another machine produces only bolts at the rate of 75 bolts per minute and needs to be cleaned for 10 min after production of every 1500 bolts. If both the machines start production at the same time, what is the minimum duration required for producing 9000 pairs of nuts and bolts?
(a) 130 min (b) 135 min
(c) 170 min (d) 180 min

63. Three consecutive positive integers are raised to the first, second and third powers respectively and then added. The sum so obtained is a perfect square whose square root equals the total of the three original integers. Which of the following best describes the minimum, say m, of these three integers?
(a) $1 \le m \le 3$ (b) $4 \le m \le 6$
(c) $7 \le m \le 9$ (d) $10 \le m \le 12$

Common Data for Questions 64 and 65

The average life expectancy for the United States population as a whole is 73.9 yr, but children born in Hawaii will live an average of 77 yr, and those born in Louisiana, 71.7 yr. If a newly wed couple from Louisiana were to begin their family in Hawaii, their children would live longer than if the couple began their family in Louisiana.

64. Which of the following, if true, would most significantly strengthen the conclusion drawn in the passage?
(a) 25% of all Louisianians who move to Hawaii live longer than 22 yr
(b) Over the last decade, average life expectancy has risen at a higher rate for Louisianians than for Hawaiians
(c) Environmental factors tending to favour longevity are abundant in Hawaii and less numerous in Louisiana
(d) As population density increases in Hawaii, life expectancy figures for the state are likely to be revised downward

65. Which of the following, if true, would most seriously weaken the conclusion drawn in the passage?
(a) Insurance company statisticians do not believe that moving to Hawaii will significantly lengthen the average Louisiana life
(b) The governor of Louisiana has falsely alleged that statistics of his state are inaccurate
(c) The longevity attributed to Hawaii's current population is attributed mostly to genetically determined factors
(d) 30% of all Louisianians can expect to live longer than 77 yr