GATE
2023
AEROSPACE
ENGINEERING

Exam held on 11th Feb, 2023 Afternoon Session

QUESTIONS & SOLUTIONS

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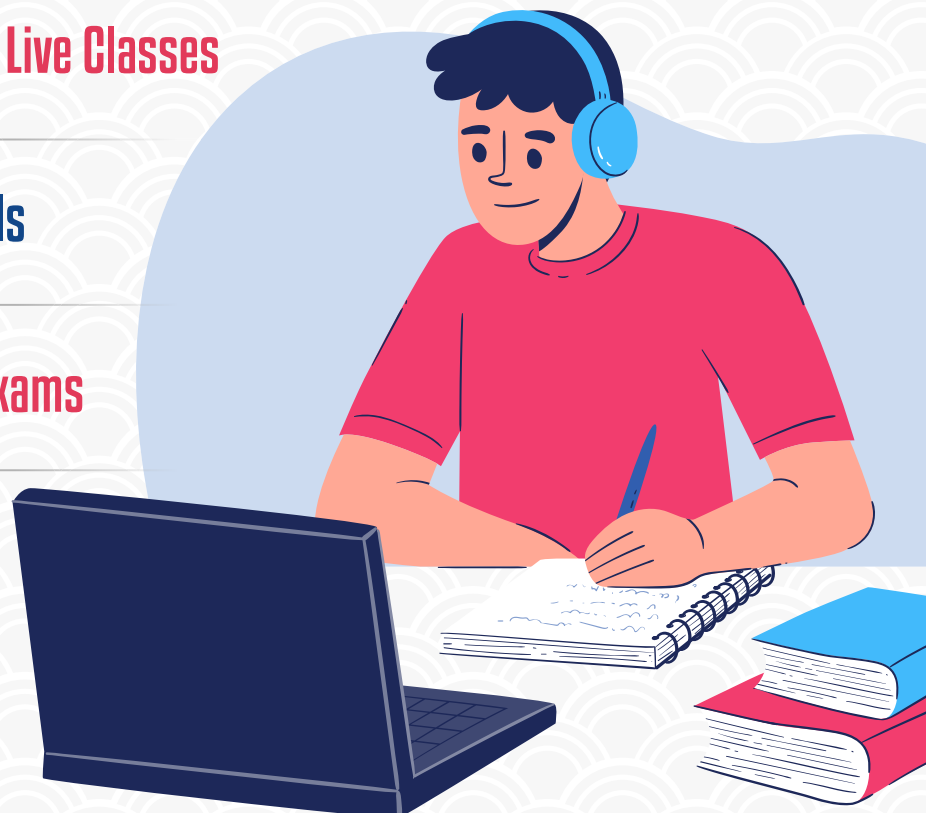November 1st 2023

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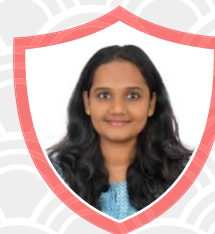Mr. **Vagicharla Dinesh** *(Lovely Professional Univ Panjab)*

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GATE 2023
AEROSPACE ENGINEERING

General Aptitude – GA
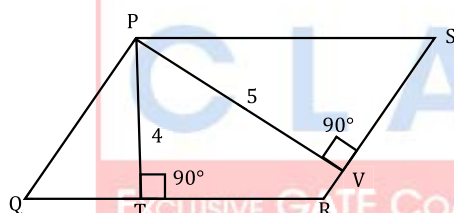
Q. 1 – Q. 5 Carry ONE mark Each.

1. "You are delaying the completion of the task. Send _____ contributions at the earliest."

   (A) you are
   (B) your
   (C) you're
   (D) yore

2. References : _____ : : Guidelines : Implement (By word meaning)

   (A) Sight
   (B) Site
   (C) Cite
   (D) Plagiarise

3. In the given figure, PQRS is a parallelogram with PS = 7 cm, PT = 4 cm and PV = 5 cm. What is the length of RS in cm? (The diagram is representative.)

   (A) 20/7
   (B) 28/5
   (C) 9/2
   (D) 35/4

4. In 2022, June Huh was awarded the Fields medal, which is the highest prize in Mathematics.

   When he was younger, he was also a poet. He did not win any medals in the International Mathematics Olympiads. He dropped out of college.

   Based only on the above information, which one of the following statements can be logically inferred with certainty?

   (A) Every Fields medalist has won a medal in an International Mathematics Olympiad.

   (B) Everyone who has dropped out of college has won the Fields medal.

   (C) All Fields medalists are part-time poets.

   (D) Some Fields medalists have dropped out of college.

5. A line of symmetry is defined as a line that divides a figure into two parts in a way such that each part is a mirror image of the other part about that line.

   The given figure consists of 16 unit squares arranged as shown. In addition to the three black squares, what is the minimum number of squares that must be coloured black, such that both PQ and MN form lines of symmetry? (The figure is representative)
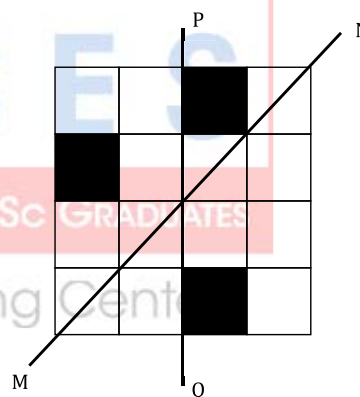
   (A) 3
   (B) 4
   (C) 5
   (D) 6

Q. 6 – Q. 10 Carry TWO marks Each.

6. Human beings are one among many creatures that inhabit an imagined world. In this imagined world, some creatures are cruel. If in this imagined world, it is given that the statement "Some human beings are not cruel creatures" is FALSE, then which of the following set of statement(s) can be logically inferred with certainty?

   (i) All human beings are cruel creatures.

(ii) Some human beings are cruel creatures.

(iii) Some creatures that are cruel are human beings.

(iv) No human beings are cruel creatures.

(A) only (i) (C) only (i) and (ii)
(B) only (iii) and (iv) (D) (i), (ii) and (iii)

7. To construct a wall, sand and cement are mixed in the ratio of 3:1. The cost of sand and that of cement are in the ratio of 1:2.
If the total cost of sand and cement to construct the wall is 1000 rupees, then what is the cost (in rupees) of cement used?

(A) 400 (C) 800
(B) 600 (D) 200

8. The World Bank has declared that it does not plan to offer new financing to Sri Lanka, which is battling its worst economic crisis in decades, until the country has an adequate macroeconomic policy framework in place. In a statement, the World Bank said Sri Lanka needed to adopt structural reforms that focus on economic stabilisation and tackle the root causes of its crisis. The latter has starved it of foreign exchange and led to shortages of food, fuel, and medicines. The bank is repurposing resources under existing loans to help alleviate shortages of essential items such as medicine, cooking gas, fertiliser, meals for children, and cash for vulnerable households.
Based only on the above passage, which one of the following statements can be inferred with certainty?

(A) According to the World Bank, the root cause of Sri Lanka's economic crisis is that it does not have enough foreign exchange.

(B) The World Bank has stated that it will advise the Sri Lankan government about how to tackle the root causes of its economic crisis.

(C) According to the World Bank, Sri Lanka does not yet have an adequate macroeconomic policy framework.

(D) The World Bank has stated that it will provide Sri Lanka with additional funds for essentials such as food, fuel, and medicines.

9. The coefficient of x^4 in the polynomial $(x-1)^3(x-2)^3$ is equal to _____.

(A) 33 (C) 30
(B) -3 (D) 21

10. Which one of the following shapes can be used to tile (completely cover by repeating) a flat plane, extending to infinity in all directions, without leaving any empty spaces in between them? The copies of the shape used to tile are identical and are not allowed to overlap.

(A) circle
(B) regular octagon
(C) regular pentagon
(D) rhombus

Aerospace Engineering – AE

Q. 11 – Q. 35 Carry ONE mark Each.

11. The direction in which a scalar field $\phi(x, y, z)$ has the largest rate of change at any point with position vector $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ is the same as that of the vector

(A) $\nabla\phi$ (C) $\phi\vec{r}$
(B) $\nabla \times (\phi\vec{r})$ (D) $(\nabla\phi \cdot d\vec{r})\vec{r}$

12. If a monotonic and continuous function $y = f(x)$ has only one root in the interval $x_1 < x < x_2$, then

(A) $f(x_1)f(x_2) > 0$ (C) $f(x_1)f(x_2) < 0$
(B) $f(x_1)f(x_2) = 0$ (D) $f(x_1) - f(x_2) = 0$

13. Consider the one-dimensional wave equation $\frac{\partial u}{\partial t} + \frac{\partial u}{\partial x} = 0$ for $-\infty < x < \infty, t \geq 0$. For an initial condition $u(x, 0) = e^{-x^2}$, the solution at t = 1 is

(A) $u(x, 1) = e^{-(x-1)^2}$ (C) $u(x, 1) = e^{-x^2}$
(B) $u(x, 1) = e^{-1}$ (D) $u(x, 1) = e^{-(x+1)^2}$

14. A two-dimensional potential flow solution for flow past an airfoil has a streamline pattern as shown in the figure. Which of the following conditions is additionally required to satisfy the Kutta condition?

(A) Addition of a source of strength Q > 0
(B) Addition of a source of strength Q < 0
(C) Addition of a circulation of strength $\Gamma > 0$ (counter-clockwise)
(D) Addition of a circulation of strength $\Gamma < 0$ (clockwise)

15. Consider the Blasius solution for the incompressible laminar flat plate boundary layer. Among the following options, select the correct relation for the development of the momentum thickness θ with distance x from the leading edge along the length of the plate.

(A) $\theta \propto x^{2/3}$ (C) $\theta \propto x^{1/7}$
(B) $\theta \propto x^{1/2}$ (D) $\theta \propto x^{-2/3}$

16. In a two-dimensional potential flow, the doublet is a limit of the superposition of
(A) a uniform stream and a source
(B) a source and a sink of equal strength
(C) a uniform stream and a sink
(D) a source and a vortex

17. An ideal glider has drag characteristics given by $C_D = C_{D_0} + C_{D_i}$, where $C_{D_i} = KC_L^2$ is the induced drag coefficient, C_L is the lift coefficient, and K is a constant. For maximum range of the glider, the ratio C_{D_0}/C_{D_i} is

(A) 1   (C) 3
(B) 1/3   (D) 3/2

18. The figures shown in the options are schematics of airfoil shapes (not to scale). For a civilian transport aircraft designed for a cruise Mach number of 0.8, which among them is aerodynamically best suited as a wing section?

(A)

(B)

(C)

(D)
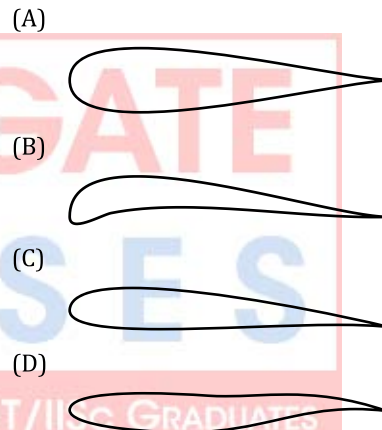
19. For a longitudinally statically stable aircraft, which one of the following represents the relationship between the coefficient of pitching moment about the center of gravity $C_{m_{cg}}$ and absolute angle of attack α_a?
(Note: nose-up moment is positive.)

(A)

(B)

(C)

(D)
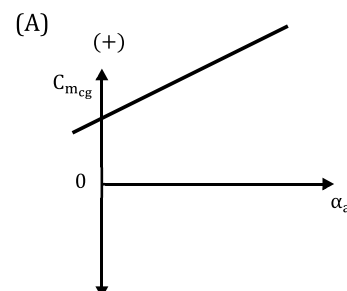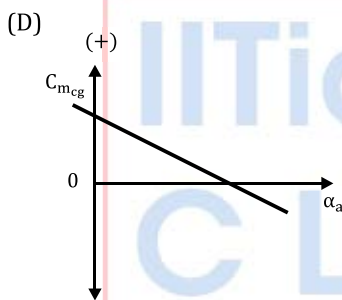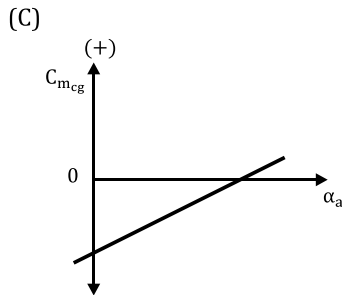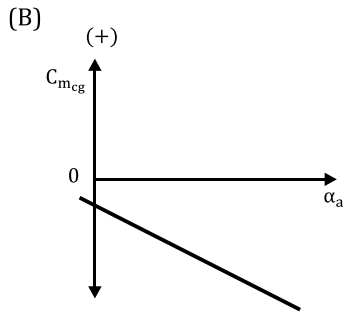
20. In a single-spool aviation turbojet engine, which of the following is the correct relationship between the total work output W_T of a 2-stage axial turbine and the total work required W_C by a 6-stage axial compressor, neglecting losses?

(A) $W_T = 2W_C$ (C) $W_T = W_C$

(B) $W_T = 6W_C$ (D) $W_T = 3W_C$

21. For a stage of a 50% reaction ideal axial flow compressor (symmetrical blading), select the correct statement from the options given.

(A) The stagnation enthalpy rise across the rotor is 50% of the rise across the stage.

(B) The static enthalpy rise across the rotor is 50% of the rise across the stage.

(C) Axial velocity component of the flow at the rotor exit is 50% of that at the rotor entry.

(D) The static pressure rise across the rotor is 50% of the rise across the stator.

22. An aircraft is cruising with a forward speed V_a and the jet exhaust speed relative to the engine at the exit is V_j. If $V_j/V_a = 2$ what is the propulsive efficiency?

(A) 0.50   (C) 0.33

(B) 1.00   (D) 0.67

23. Consider the four basic symmetrical flight loading conditions corresponding to the corners of a typical V-n diagram. For one of these flight loading conditions, it is observed that

(i) the compressive bending stresses have a maximum value in the bottom aft region (see figure) of the wing cross-section; and

(ii) the tensile bending stresses are maximum in the upper forward region (see figure) of the wing cross-section.

For the preceding observations, select the corresponding flight loading condition from the options given.
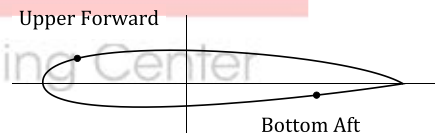
(A) Positive high angle of attack

(B) Positive low angle of attack

(C) Negative high angle of attack

(D) Negative low angle of attack

24. Which one of the following figures represents the qualitative variation of absolute deceleration $\left|\frac{dV}{dt}\right|$ with altitude h (measured from the mean sea level) for a space vehicle undergoing a ballistic entry into the Earth's atmosphere?

(A)

(B)

(C)

(D)
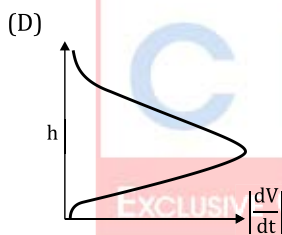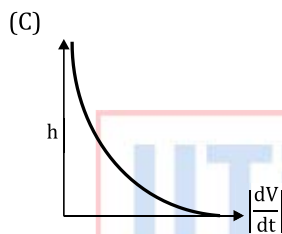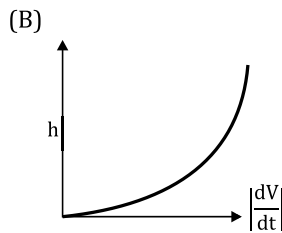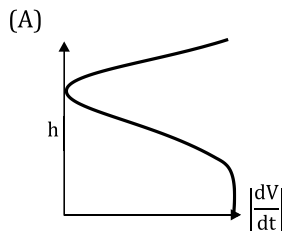
25. Which of the following statement(s) is/are true about harmonically excited forced vibration of a single degree-of-freedom linear spring-mass-damper system?

(A) The total response of the mass is a combination of free vibration transient and steady-state response.

(B) The free vibration transient dies out with time for each of the three possible conditions of damping (under-damped, critically damped, and over-damped).

(C) The steady-state periodic response is dependent on the initial conditions at the time of application of external forcing.

(D) The rate of decay of free vibration transient response depends on the mass, spring stiffness and damping constant.

26. Which of the following statement(s) is/are true about the state of stress in a plane?

(A) Maximum or major principal stress is algebraically the largest direct stress at a point.

(B) The magnitude of minor principal stress cannot be greater than the magnitude of major principal stress.

(C) The planes of maximum shear stress are inclined at 90 degrees to the principal axes.

(D) The normal stresses along the planes of maximum shear stress are equal.

27. Which of the following statement(s) is/are true about the ribs of an airplane wing with semi-monocoque construction?

(A) For a rectangular planform wing, the dimensions of the ribs DO NOT depend on their spanwise position in the wing.

(B) Ribs increase the column buckling stress of longitudinal stiffeners connected to them.

(C) Ribs increase plate buckling stress of the skin panels.

(D) Ribs help in maintaining aerodynamic shape of the wing.

28. From the options given, select all that are true for turbofan engines with afterburners.

(A) Turning afterburner ON increases specific fuel consumption.

(B) Turbofan engines with afterburners have variable area nozzles.

(C) Turning afterburner ON decreases specific fuel consumption.

(D) Turning afterburner ON increases stagnation pressure across the engine.

29. Which of the following statement(s) is/are true with respect to eigenvalues and eigenvectors of a matrix?

(A) The sum of the eigenvalues of a matrix equals the sum of the elements of the principal diagonal.

(B) If λ is an eigenvalue of a matrix A, then $1/\lambda$ is always an eigenvalue of its transpose (A^T).

(C) If λ is an eigenvalue of an orthogonal matrix A, then $1/\lambda$ is also an eigenvalue of A.

(D) If a matrix has n distinct eigenvalues, it also has n independent eigenvectors.

30. For studying wing vibrations, a wing of mass M and finite dimensions has been idealized by assuming it to be supported using a linear spring of equivalent stiffness k and a torsional spring of equivalent stiffness k_θ as shown in the figure.

The centre of gravity (CG) of the wing idealized as an airfoil is marked in the figure. The number of degree(s) of freedom for this idealized wing vibration model is _____. (Answer in integer)
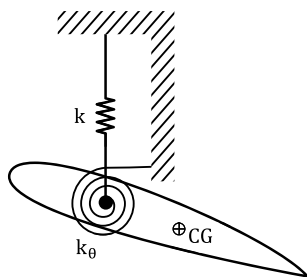

31. The system of equations

$x - 2y + \alpha z = 0$

$2x + y - 4z = 0$

$x - y + z = 0$

has a non-trivial solution for $\alpha = $_____. (Answer in integer)

32. An airplane weighing 40 kN is landing on a horizontal runway during which it is retarded by an arresting cable mechanism. The tension in the arresting cable at a given instant, as shown in the figure, is 100 kN. Assuming that the thrust from the engine continues to balance airplane drag, the magnitude of horizontal load factor is _____. (round off to one decimal place)
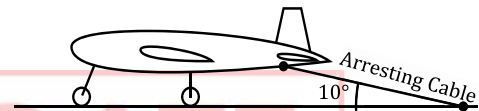
33. The ratio of the speed of sound in H_2 (molecular weight 2 kg/kmol) to that in N_2 (molecular weight 28 kg/kmol) at temperature 300 K and pressure 2 bar is ___. (round off to two decimal places)

34. Airplane A and Airplane B are cruising at altitudes of 2 km and 4 km, respectively. The free stream density and static pressure at altitude 2 km are 1.01 kg/m^3 and 79.50 kPa, respectively, and at altitude 4 km, they are 0.82 kg/m^3 and 61.70 kPa, respectively. The differential pressure reading from the pitot-static tubes is 3 kPa for both the airplanes. Assuming incompressible flow, the ratio of cruise speeds of Airplane A to Airplane B is _____. (round off to two decimal places)

35. A supersonic vehicle powered by a ramjet engine is cruising at a speed of 1000 m/s. The ramjet engine burns hydrogen in a subsonic combustor to produce thrust. The heat of combustion for hydrogen is 120 MJ/kg. The

overall efficiency of the engine η_0, defined as the ratio of propulsive power to the total heat release in the combustor, is 40%. Taking acceleration due to gravity $g_0 = 10 \text{ m/s}^2$, the specific impulse of the engine is _____seconds. (round off to the nearest integer).

Q. 36 – Q. 65 Carry TWO marks Each.

36. Given the function $y(x) = (x + 3)(x - 2)$, for $-4 < x < 4$. What is the value of x at which the function has a minimum?

    (A) $-3/2$ (C) $1/2$

    (B) $-1/2$ (D) $3/2$

37. A supersonic aircraft has an air intake ramp that can be rotated about the leading edge O such that the shock from the leading edge meets the cowl lip as shown in the figure. Select all the correct statement(s) as per oblique shock theory when the flight Mach number M is increased.
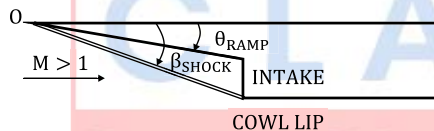
    (A) It is always possible to find a ramp setting θ_{RAMP} such that the shock still meets the cowl lip (β_{SHOCK} remains the same).

    (B) If θ_{RAMP} is held fixed, the shock angle β_{SHOCK} will increase.

    (C) If M exceeds a critical value, it would NOT be possible to find a ramp setting θ_{RAMP} such that the shock still meets the cowl lip (β_{SHOCK} remains the same).

    (D) Shock angle $\beta_{SHOCK} < \sin^{-1}(1/M)$

38. Two missiles A and B powered by solid rocket motors have identical specific impulse, liftoff mass of 5600 kg each, and burn durations of $t_A = 30S$ and $t_B = 70s$, respectively. The propellant mass flow rates, $\dot{m}_A$ and $\dot{m}_B$, for missiles A and B, respectively, are given by

$\dot{m}_A = 120 \text{ kg/s}, \quad 0 \le t \le 30$

$\dot{m}_B = 70 \text{ kg/s}, \quad 0 \le t \le 70$

Neglecting gravity and aerodynamic forces, the relationship between the final velocities V_A and V_B of missiles A and B, respectively, is given by

(A) $V_A = 4.1 \, V_B$ (C) $V_A = 0.5 V_B$

(B) $V_A = V_B$ (D) $V_A = 0.7 V_B$

39. A perfect gas stored in a large reservoir exhausts into the atmosphere through a convergent duct. The reservoir pressure is P_0 and temperature is T_0. The jet emerges from the nozzle at choked conditions with average velocity u, Mach number M, pressure p, temperature T, and density ρ. If the reservoir pressure is increased, then
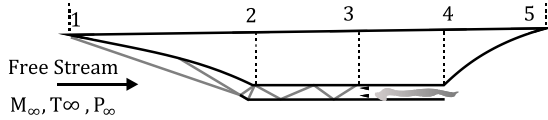
(A) u, M, p, T, and ρ increase

(B) u, p, T, and ρ increase, but M remains the same

(C) u, M, and T remain the same, but p and ρ increase

(D) u, M, T and ρ remain the same, but p increases

40. Consider a general aviation airplane with weight 10 kN and a wing planform area of 15 m^2. The drag coefficient of the airplane is given as $C_D = C_{D_0} + K C_L^2$ with $C_{D_0} = 0.025$ and $K = 0.05$. For level flight at an altitude where the density is 0.60 kg/m^3 and thrust 1 kN, the maximum cruise speed is____. (Rounded off to the nearest integer)

(A) 87 m/s   (C) 36 m/s

(B) 30 m/s   (D) 101 m/s

41. A scramjet engine features an intake, isolator, combustor, and a nozzle, as shown in the schematic. Station 3 indicates the combustor entry point. Assume stagnation enthalpy to be constant between Stations 1 and 3, and air to be a calorically perfect gas with specific heat

ratio γ. Select the correct expression for Mach number M_3 at the inlet to the combustor from the options given.

Free Stream
$M_\infty, T\infty, P_\infty$

(A) $M_3 = M_\infty \sqrt{\left(\dfrac{2}{\gamma-1}\right)\left(\dfrac{T_\infty}{T_3}-1\right)}$

(B) $M_3 = \sqrt{\left(\dfrac{2}{\gamma-1}\right)\left\{\dfrac{T_\infty}{T_3}\left[1+\left(\dfrac{\gamma-1}{2}\right)M_\infty^2\right]-1\right\}}$

(C) $M_3 = M_\infty \sqrt{\dfrac{T_\infty}{T_3}}$

(D) $M_3 = \sqrt{\left(\dfrac{\gamma+1}{2}\right)\left(\dfrac{T_\infty}{T_3}-1\right)M_\infty^2 - 1}$

42. Consider the equation $\dfrac{dy}{dx} + ay = \sin \omega x$, where a and ω are constants. Given $y = 1$ and $x = 0$, select all correct statement(s) from the following as $x \to \infty$.

(A) $y \to 0$ if $a \neq 0$

(B) $y \to 1$ if $a = 0$

(C) $y \to A \exp(|a|x)$ if $a < 0$; A is constant

(D) $y \to B \sin(\omega x + c)$ if $a > 0$; B and C are constant

43. Given the vectors

$\vec{A} = 9\hat{i} - 5\hat{j} + 2\hat{k}$

$\vec{B} = 11\hat{i} + 4\hat{j} + \hat{k}$

$\vec{C} = -7\hat{i} + 14\hat{j} - 3\hat{k}$

Which of the following statement(s) is/are TRUE?

(A) Vectors $\vec{A}, \vec{B}$ and $\vec{C}$ are coplanar.

(B) The scalar triple product of the vectors $\vec{A}, \vec{B}$ and $\vec{C}$ is zero.

(C) $\vec{A}$ and $\vec{B}$ are perpendicular.

(D) $\vec{C}$ is parallel to $\vec{A} \times \vec{B}$

44. Consider a one-dimensional inviscid supersonic flow in a diverging duct with heat addition (Q_{in}) as shown. Which of the following statement(s) is/are always TRUE?


M_1, T_1, P_1 M_2, T_2, P_2

Q_{in}
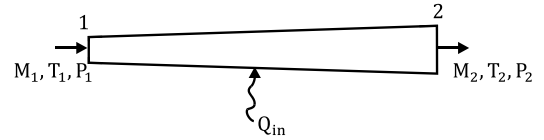
(A) Mach number, $M_2 > M_1$

(B) Stagnation pressure, $P_1^0 > P_2^0$

(C) Static pressure, $P_2 > P_1$

(D) Stagnation temperature, $T_1^0 < T_2^0$

45. Consider the International Standard Atmosphere (ISA) with h being the geopotential altitude (in km) and dT/dh being the temperature gradient (in K/m). Which of the following combination(s) of $\left(h, \dfrac{dT}{dh}\right)$ is/are as per ISA?

(A) $(7, -6.5 \times 10^{-3})$

(B) $(9, 4 \times 10^{-3})$

(C) $(15, 0)$

(D) $(35, 3 \times 10^{-3})$

46. For an airfoil, which of the relations given about the critical Mach number M_{cr} and drag divergence Mach number M_{dd} is/are correct?

(A) $M_{cr} < M_{dd}$ (C) $M_{dd} < 1.0$

(B) $M_{cr} < 1.0$ (D) $M_{cr} > 1.0$

47. Which of the following statement(s) about the elastic flexural buckling load of columns is/are correct?

(A) The buckling load increases with increase in flexural rigidity of the column.

(B) The buckling load increases with increase in the length of the column.

(C) The boundary conditions of the column affect the buckling load.

(D) The buckling load is NOT directly dependent on the density of the material used for the column.

48. The thickness of a uniform hollow circular shaft is equal to the difference between the outer radius and the inner radius. The ratio of the inner diameter to outer diameter of the shaft is 0.5. For the shaft reacting to an applied torque, the ratio of the maximum shear stress τ to the maximum shear stress $\tau_{\text{thin-wall}}$ obtained using the thin-wall approximation is _____. (Round off to one decimal place)

49. A rigid bar AB is subjected to a uniformly distributed load of 100 N/m as shown in the figure. The bar is supported by rod CD, with A, C, and D as pin joints. The rod CD has axial stiffness of 40 N/mm. The vertical deflection at point D is _____ mm. (round off to nearest integer)
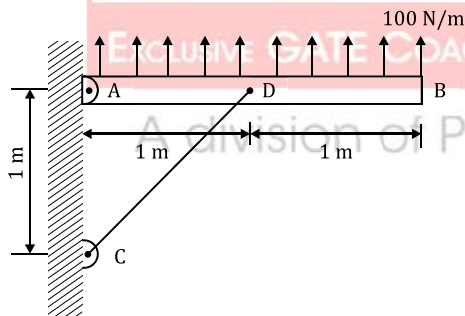
50. A cantilever beam of length 2a is loaded at the tip with force F as shown in the figure. The beam is supported in the middle by a roller with a pin. The magnitude of moment reaction at the built-in end of the beam is αFa, where α is _____ . (round off to one decimal place)
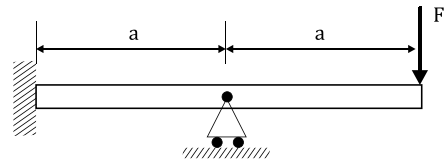
51. A single degree-of-freedom spring-mass-damper system has viscous damping ratio of 0.1. The mass is given an initial displacement of 10 cm without imparting any velocity. After exactly two complete cycles of oscillation (i.e., after time $2T_d$, where T_d is the period of the damped vibration), the amplitude of the displacement is _____ cm. (round off to two decimal place)

52. The shear flow distribution in a single cell, thin-walled beam under the action of an arbitrary shear load S_y applied at the shear centre S is shown in the figure. The cell has horizontal symmetry with booms marked by 1 to 4 that carry direct stresses. The shear modulus G is the same for all the walls, and the area of the cell is 135000 mm². With respect to the point O marked in the figure, the distance to the shear centre S is _____ mm. (round off to the nearest integer)
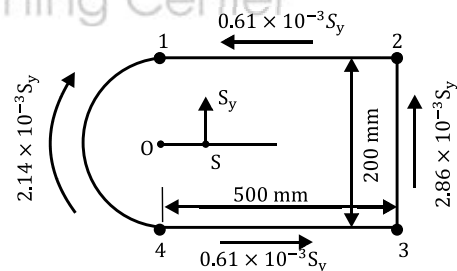
53. Consider a thin-walled cylindrical pressure vessel made of an alloy with yield strength of 300 MPa. The vessel has end caps to contain the pressure. The ratio of radius of the vessel to its wall thickness is 100. As per the von Mises yield

criterion, the internal pressure that would cause the failure of the vessel is _____ MPa. (round off to two decimal places)

54. Consider the differential equation

$$x^2 \frac{d^2y}{dx^2} + 4x \frac{dy}{dx} + 2y = 0 \text{ for } x \geq 1$$

with initial conditions $y = 0, \frac{dy}{dx} = 1$ at $x = 1$. The value of y at $x = 2$ is _____. (round off to two decimal places).

55. The operating characteristics of a pump were measured to be $C_p = a\Phi^2$, where power coefficient $C_p = \frac{P}{\rho \omega^3 D^5}, \Phi$ is the flow coefficient, a is a constant, D is a length scale, ω is the rotation rate, ρ is fluid density, and P is the power required. The flow coefficient is a dimensionless volume flow rate scaled with ω and D . Assuming that the flow rate remains the same, if the rotation rate is increased to 1.25ω, the power changes to αP . The value of α is _____ . (round off to two decimal places)

56. A thin cambered airfoil has lift coefficient $c_l = 0$ at an angle of attack $\alpha = -1.1°$. Assuming that stall occurs at much larger α , the c_l at $\alpha = 4°$ is _____. (round off to two decimal places)

57. In a potential flow, a uniform stream of strength U directed along the x-axis and four line sources (2-dimensional) of strengths $\frac{\pi}{2}, \frac{-\pi}{3}, \frac{\pi}{4}, \frac{-\pi}{5}$ are placed along the x-axis at x = 0, 1, 2 and 3, respectively. The strength of an additional line source to be placed at x = 4 such that a closed streamline encircles all five sources is _____. (round off to two decimal places).

58. Enstrophy is defined as the square of the magnitude of vorticity. For the three-dimensional velocity field

$\vec{V} = (4x - 1.5y + 2.5z)\hat{i} + (1.5x - 1.5y)\hat{j} + (0.7xy)\hat{k}$,

the enstrophy at location (1, 1, 1) is _____ . (round off to two decimal places)

59. An airplane with wing planform area of 20 m^2 and weight 8 kN is flying straight and level with a speed of 100 m/s. The total drag coefficient is 0.026 and the air density is 0.7 kg/m^3. The total thrust required to introduce a steady climb angle of 0.1 radians is ___ N. (round off to the nearest integer)

60. The maximum permissible load factor and the maximum lift force coefficient for an airplane is 7 and 2, respectively. For a wing loading of 6500 N/m^2 and air density 1.23 kg/m^3, the speed yielding the highest possible turn rate in the vertical plane is _____ m/s. (round off to the nearest integer)

61. A gas turbine combustor is burning methane and air at an equivalence ratio $\phi = 0.5$, where $\phi = \frac{F/A}{\left[\frac{F}{A}\right]_{stoich}}$ and $[F/A]_{stoich}$ is the ratio of mass flow rate of fuel to the mass flow rate of air at stoichiometry. If the air flow rate is $\dot{m}_{air} = 20$ kg/s then the mass flow rate of methane is _____ kg/s. (round off to two decimal places)

62. The universal gravitational constant is 6.67×10^{-11} Nm^2/kg^2. For a planet of mass 6.4169×10^{23} kg and radius 3390 km, the escape velocity is ____ km/s. (round off to one decimal place).

63. A satellite is in a circular orbit around Earth with a time period of 90 minutes. The radius of

Earth is 6370 km, mass of Earth is 5.98×10^{24} kg and the universal gravitational constant is 6.67×10^{-11} Nm^2/kg^2. The altitude of the satellite above mean sea level is ___ km. (round off to the nearest integer)

64. A centrifugal air compressor has inlet root diameter of 0.25 m and the outlet diameter of the impeller is 0.6 m. The pressure ratio is 5.0. The air at the inlet of the rotor is at 1 atm and 25℃. The polytropic efficiency is 0.8 and slip factor is

0.92. Use $C_p = 1.004$ kJ/kg-K and $\gamma = 1.4$. The impeller speed in revolutions per minute (RPM) is _____. (round off to the nearest integer)

65. Consider a cryogenic liquid rocket engine using an expander cycle with liquid hydrogen and liquid oxygen as the two propellants. The mass flow rate of hydrogen $\dot{m}_{H_2}$ into the combustion chamber is 32 kg/s , and the mass flow rate of oxygen $\dot{m}_{O_2}$ into the chamber is such that $\dot{m}_{O_2}/\dot{m}_{H_2} = 8$. The combustion of hydrogen and oxygen is at stoichiometry. Assuming that the rate of the forward reaction is much larger than that of the reverse reaction, the rate of formation of H$_2$O is _____ kmol/s. (round off to the nearest integer)

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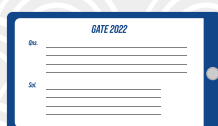## Distance Learning Program

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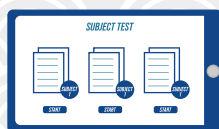Online Doubt Support
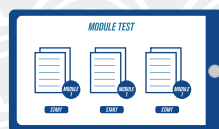
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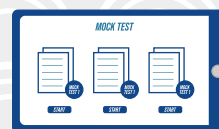
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Explanations | GATE 2023 - Aerospace Engineering

General Aptitude – GA

1. **[Ans. B]**

2. **[Ans. C]**

3. **[Ans. B]**

   Taking area of parallelogram

   $7 \times 4 = 5 \times x$

   $\Rightarrow x = \dfrac{28}{5}$

4. **[Ans. D]**

5. **[Ans. C]**

6. **[Ans. D]**

7. **[Ans. A]**

	Sand	:	Cement
Quantity	3	:	1
Cost	1	:	2
Total Cost	3	:	2

   $\therefore$ Cost of Cement $= \dfrac{2}{5} \times 1000 = 400$

8. **[Ans. C]**

9. **[Ans. A]**

   $(x-1)^3(x-2)^3$

   As $(a-b)^3 = a^3 - b^3 - 3ab\,(a-b)$

   $= [x^3 - 1 - 3x(x-1)][x^3 - 8 - 3(x)(2)(x-2)]$

   $= (x^3 - 1 - 3x^2 + 3x)(x^3 - 8 - 6x^2 + 12x)$

   Coefficeint of $x^4 = 12 + 18 + 3 = 33$

10. **[Ans. D]**

    A rhombus tessellation is a tiling pattern made up of congruent rhombus shapes that fit together perfectly, without any gaps or overlaps, to cover a flat plane. Each rhombus in the tessellation has equal side lengths but opposite interior angles are equal, which means that adjacent rhombi are rotated 180 degrees from each other.
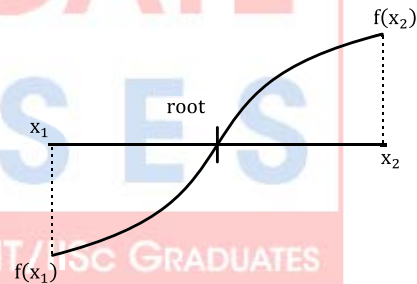
Aerospace Engineering – AE

11. **[Ans. A]**

    For $\phi(x, y, z)$, the largest rate of change denotes grad (ϕ), i.e., $\nabla\phi$.

12. **[Ans. C]**

    Given $f(x)$ is monotonic and continuous with only one root in the interval $x_1 < x < x_2$ i.e.,

    $\therefore f(x_1) \cdot f(x_2) < 0$

13. **[Ans. A]**

    For a one-dimensional heat wave equation of the form $au_x + bu_y = 0$, the generalized solution would be of the form $u(x, y) = f(bx - ay)$.

    Now, given $\dfrac{\partial u}{\partial x} + \dfrac{\partial u}{\partial t} = 0$

    $\therefore u(x, t) = f(x - t)$

    Given, $u(x, 0) = e^{-x^2} \Rightarrow u(x, t) = e^{-(x-t)^2}$

14. **[Ans. D]**

    For the given flow in the figure to achieve a positive lift and a smooth flow over the airfoil, an additional clockwise $(\Gamma < 0)$ circulation is required.

15. **[Ans. B]**

From Blasius solution,

$\frac{\theta}{x} = \frac{C_1}{\sqrt{Re_x}}$ and $R_{e_x} = \frac{\rho Vx}{\mu}$

$\therefore \theta \propto x^{1/2}$

16. **[Ans. B]**

Doublet = $\underbrace{\text{Source + Sink}}_{\text{of equal strength}}$

17. **[Ans. A]**

For gliding , flight,

$(Range)_{max} \Rightarrow \left(\frac{L}{D}\right)_{max} \Rightarrow D_{min}$

$\therefore$ At $D_{min} \Rightarrow C_{D_o} = C_{D_i}$

18. **[Ans. D]**

In general at high subsonic speed, supercritical airfoil is preferred so that if increases the critical Mach number as well as the drag divergence Mach number of the aircraft.

19. **[Ans. D]**

For longitudinal stability of aircraft,

i $C_{mo} > 0$

ii. $\frac{\partial C_m}{\partial \alpha} < 0$

20. **[Ans. C]**

Given,

Total work output of 2-stage axial turbine = W_T

Total work output of 6-stage axial compressor = W_C.

As there were no losses, $W_T = W_C$

21. **[Ans. B]**

Degree of reaction is defined as

$\Rightarrow R = \frac{(\Delta h)_{rotor}}{(\Delta h)_{stage}} = \frac{(\Delta p)_{rotor}}{(\Delta p)_{stage}}$

22. **[Ans. D]**

We know,

$\eta_p = \frac{2 \times \frac{V_a}{V_j}}{1 + \frac{V_a}{V_j}}$

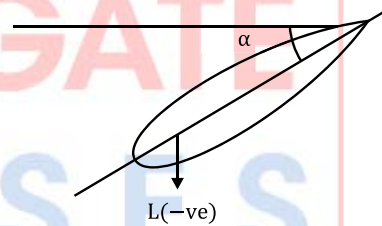$\Rightarrow \eta_p = \frac{2 \times \frac{1}{2}}{1 + \frac{1}{2}}$

$\Rightarrow \eta_p = 0.67$

23. **[Ans. D]**

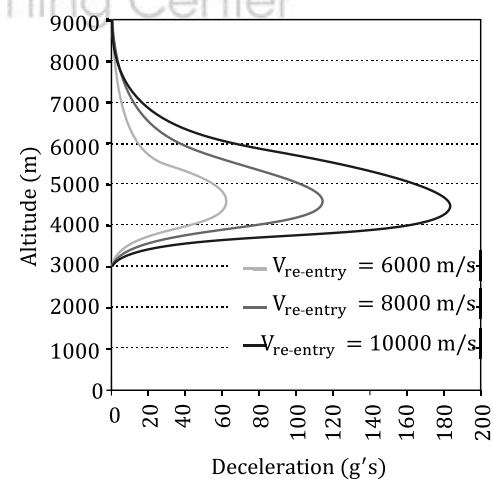At low negative angle attack, due to moment arm

bottom Aft – Compression maximum
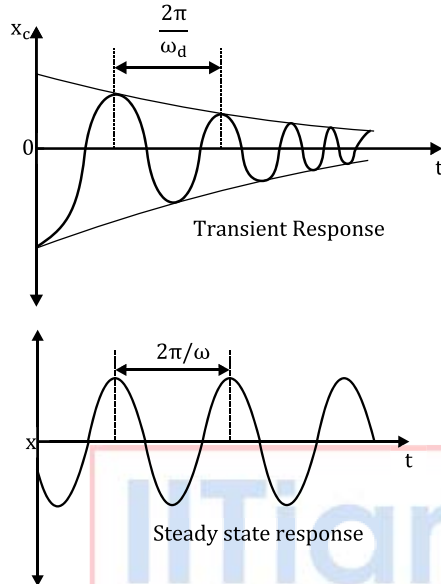
Upper forward – Tension maximum.

24. [Ans. D]

Deceleration profile of a vehicle re-entering from space is as,

25. **[Ans. A, B, D]**

$x = x_c + x_p$

$$= A_2 e^{-\zeta \omega_n t} \sin\left[\left(\sqrt{1-\zeta^2}\right) \omega_n t + \phi_2\right]$$

$$+ \frac{X_{st}}{\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2\zeta \frac{\omega}{\omega_n}\right]^2}} \sin(\omega t - \phi)$$

Transient Response

Steady state response

Also, for all three possible conditions of damping (practically) the free vibration transient dies out with time.

26. **[Ans. A, D]**

Major principal stress

$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$ is algebraically

the Largest direct stress at a point

- Magnitude of minor principal stress can be greater than that of major principal stress.
- Plane of maximum shear stress is inclined 45° with the principal axes.
- Normal stresses along the planes of maximum shear stress are equal.

  i.e., $\sigma_n^* = \frac{\sigma_1 + \sigma_2}{2} = \frac{\sigma_x + \sigma_y}{2}$

27. **[Ans. B, C, D]**

Ribs in an aircraft are used to provide structural support to the skin panels, they can influence the plate buckling stress of the skin

and play an important role in maintaining the aerodynamic shape of the wing. Ribs also increase the column buckling stress of longitudinal stiffeners connected to them.

28. **[Ans. A, B]**

When an after burner is 'ON', additional mass flow rate of fuel is needed thus SFC also increases.

- In an afterburner, combustion is isobaric so stagnation pressure doesn't change.
- But due to addition of heat by adding the fuel the stagnation temperature increases.
- $\dot{m} \propto \frac{P_o}{\sqrt{T_o}} A^*$

As T_o is changing, A^* has to be changed depending on $\dot{m}$ i.e., variable area nozzle.

29. **[Ans. A, C, D]**

Eigen value of A is 'λ' then A^T will also have 'λ' as its eigen value, but not '$1/\lambda$'.

Now, Orthogonal matrix $\Rightarrow A^T = A^{-1}$,

So, "$1/\lambda$" eigen value does not correspond to 'A'

30. **[Ans. *] Range: 2 to 2**

The given wing setup will have 2 DOF, translation motion in vertical direction and rotational motion about CG.

31. **[Ans. *] Range: 3 to 3**

Given, $\overset{A}{\begin{bmatrix} 1 & -2 & \alpha \\ 2 & 1 & -4 \\ 1 & -1 & 1 \end{bmatrix}} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

For a non-trivial solution

$|A| = 0$

$\Rightarrow \begin{vmatrix} 1 & -2 & \alpha \\ 2 & 1 & -4 \\ 1 & -1 & 1 \end{vmatrix} = 0 \Rightarrow \alpha = 3$

32. **[Ans. *] Range: 2.4 to 2.6**

$\sum F_{H(net)} = T - D - F \cos 10$

$= -F \cos 10 \quad [\because T = D]$

$\therefore \left|\dfrac{\sum F_{H(net)}}{W}\right| =$ Horizontal load factor

$\qquad = \dfrac{100 \cos 10}{40} = 2.46$

33. **[Ans. *] Range: 3.5 to 4.0**

$R = \dfrac{\overline{R}}{MW} \therefore \dfrac{R_{H_2}}{R_{N_2}} = \dfrac{\overline{R}/2}{\overline{R}/28} = 14$

Now at constant temperature

$C = \sqrt{RT} \therefore \dfrac{C_{H_2}}{C_{N_2}} = \sqrt{\dfrac{R_{H_2}}{R_{N_2}}} = \sqrt{14} = 3.74$

34. **[Ans. *] Range: 0.89 to 0.91**

Differential pressure reading = Dynamic pressure (q)

Given $q_A = q_B = 3$ kPa

$\Rightarrow \dfrac{1}{2}\rho_A V_A^2 = \dfrac{1}{2}\rho_B V_B^2$

$\Rightarrow \dfrac{V_A}{V_B} = 0.9$

35. **[Ans. *] Range: 4800 to 4900**

Given, $\eta_o = \dfrac{F \times V_a}{Q \times \dot{m}}$

$\Rightarrow 0.4 = \dfrac{f \times 1000}{\dot{m} \times 120 \times 10^6}$

$\Rightarrow \dfrac{F}{\dot{m}} = 48000$ Ns/kg

$I_{sp} = \dfrac{f}{\dot{m}g} = \dfrac{48000}{10} = 4800$ sec

36. **[Ans. B]**

Given, $y = (x + 3)(x - 2)$

$\Rightarrow y = x^2 + x - 6$

$y' = 2x + 1 = 0$

$\Rightarrow x = -\dfrac{1}{2}$

$y'' = 2 > 0 \Rightarrow$ minimum

37. **[Ans. A]**

From $\theta - \beta - M$ graph

As $\theta =$ constant $\Rightarrow$ with increases in M, β decreases.

And we know , $\beta > \sin^{-1}\left(\dfrac{1}{M}\right)$

Note: it is not always possible to find ramp setting θ such that shock still meets the cowl lips.

38. **[Ans. C]**

$m_{PA} = \dot{m}_A \times t_A = 3600$ kg

$m_{PB} = \dot{m}_B \times t_B = 4900$ kg

We know,

$\Delta V = V_e \ln\left(\dfrac{m_o}{m_f}\right)$

$\Rightarrow \Delta V_A = I_{S_{PA}}\, g \ln\left(\dfrac{m_{OA}}{m_{OA} - m_{PA}}\right)$

And

$\Delta V_B = I_{S_{PB}}\, g \ln\left(\dfrac{m_{OB}}{m_{OB} - m_{PB}}\right)$

$\therefore \dfrac{\Delta V_A}{\Delta V_B} = \dfrac{\ln\left(\dfrac{5600}{2000}\right)}{\ln\left(\dfrac{5600}{700}\right)}$

$[\because \Delta V = V_{Burnolet} - V_{initial}]$

And $(V_{initial} = 0)$

$\therefore \dfrac{V_A}{V_B} = 0.495$

39. **[Ans. C]**

Given nozzle is chocked $p_e = p^* =$ constant $\times p_o$

$V_e = \sqrt{VRT^*} = \sqrt{\gamma R}\,\sqrt{\text{constant} \times T_o}$

$= C_1\sqrt{T_o}$

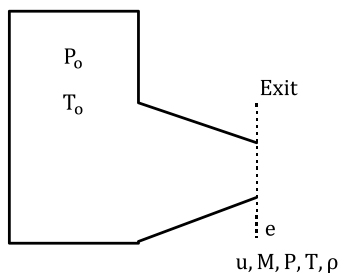$T_e = T^* =$ constant $\times T_o$

$M_e = 1$ and we know $\rho^* = \dfrac{p^*}{RT^*}$

$\Rightarrow \rho^* =$ constant $\times p_o$

$\therefore$ If p_o increases, $T_o =$ constant then p_e increases, $V_e =$ constant $T_e =$ constant, $M_e =$ constant

and ρ^* increases.

P_o
T_o
Exit
e
u, M, P, T, ρ

40. **[Ans. A]**

We know,

$$T = D = k_1 V^2 + \frac{k_2}{V^2}$$

where, $k_1 = C_{D_o} \times \frac{1}{2}\rho s = 0.1125$

$$k_2 = \frac{kW^2}{\frac{1}{2}\rho s} = 1111111.11$$

$$\therefore 1000 = 0.1125\, V^2 + \frac{1111111.11}{V^2}$$

$$\Rightarrow 1000\, V^2 = 0.1125\, V^4 + 1111111.11$$

$$\Rightarrow V_{max}^2 = 7587.14$$

$$\Rightarrow V_{max} = 87.104 \text{ m/s}$$

41. **[Ans. B]**

$$T_{01} = T_\infty \left(1 + \frac{\gamma - 1}{2} M_\infty^2\right) \text{ and}$$

$$T_{03} = T_3 \left(1 + \frac{\gamma - 1}{2} M_3^2\right)$$

Given, $T_{01} = T_{03}$

$$\Rightarrow T_\infty \left(1 + \frac{\gamma - 1}{2} M_\infty^2\right) = T_3 \left(1 + \frac{\gamma - 1}{2} M_3^2\right)$$

$$\Rightarrow \left[T_\infty + \left(\frac{\gamma - 1}{2} M_\infty^2\right) T_\infty - T_3\right] \frac{1}{T_3 \left(\frac{\gamma - 1}{2}\right)}$$

$$= M_3^2$$

$$\Rightarrow M_3^2 = \left(\frac{2}{\gamma - 1}\right)\left[\frac{T_\infty}{T_3} + \frac{\gamma - 1}{2} M_\infty^2 \frac{T_\infty}{T_3} - 1\right]$$

$$\Rightarrow M_3 = \sqrt{\left(\frac{2}{\gamma - 1}\right)\left[\frac{T_\infty}{T_3}\left(1 + \frac{\gamma - 1}{2} M_\infty^2\right) - 1\right]}$$

42. **[Ans. C, D]**

$$\frac{dy}{dx} + ay = \sin \omega x$$

For CF:

$$D + a = 0$$

$$\Rightarrow D = -a$$

$$CF \Rightarrow y = C_1\, e^{-ax}$$

For PI:

$$PI = \frac{1}{D + a}\sin \omega x$$

$$= \frac{D - a}{D^2 - a^2}\sin \omega x$$

$$\Rightarrow PI = \frac{\omega \cos \omega x - a \sin \omega x}{-\omega^2 - a^2}$$

$$\therefore y = C_1 e^{-ax} + \frac{a \sin \omega x - \omega \cos \omega x}{\omega^2 + a^2}$$

$$\therefore y = C_1 e^{-ax} + \frac{\sin(\omega x - \phi)}{\sqrt{\omega^2 + a^2}}$$
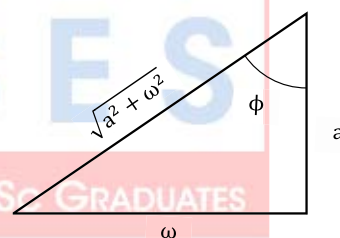
As $x \to \infty$, and

$$a > 0 \Rightarrow y = C_1 \times 0 + \frac{\sin(\omega x - \phi)}{\sqrt{\omega^2 + a^2}} \approx y$$

$$\to B \sin(\omega x + c)$$

$$a < 0 \Rightarrow y = C_1 e^{ax} + \frac{\sin(\omega x - \phi)}{\sqrt{\omega^2 + a^2}} \approx y$$

$$\to A \exp(|a|x)$$

43. **[Ans. A, B]**

Scalar triple product $= A \cdot (B \times C)$

$$B \times C = \begin{vmatrix} i & j & k \\ 11 & 4 & 1 \\ -7 & 14 & -3 \end{vmatrix}$$

$$= -26\hat{\imath} - 26\hat{\jmath} + 182\hat{k}$$

$$\therefore A \cdot (B \times C) = \left(9\hat{\imath} - 5\hat{\jmath} + 2\hat{k}\right)$$

$$\cdot \left(-26\hat{\imath} - 26\hat{\jmath} + 182\hat{k}\right)$$

$$= -234 - 130 + 364 = 0$$

$\therefore A, B, C$ are coplanar.

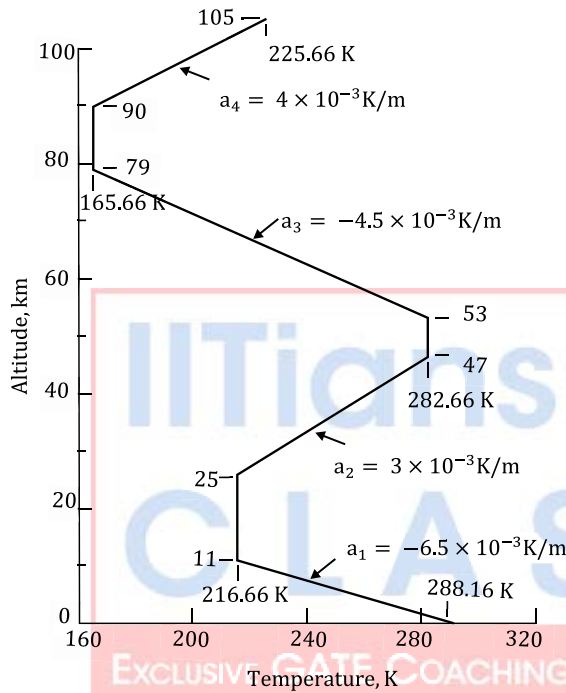$$\vec{A} \cdot \vec{B} \neq 0 \Rightarrow A, B \text{ are Not perpendicular}$$

$$\vec{A} \times \vec{B} = \begin{vmatrix} i & j & k \\ 7 & -5 & 2 \\ 11 & 4 & 1 \end{vmatrix} = -13\,\hat{\imath} + 13\hat{\jmath} + 91\hat{k}$$

$$\therefore \vec{A} \times \vec{B} \text{ is not parallel to } \vec{C}.$$

44. **[Ans. B, D]**

The given divergent duct flow resembles Rayleigh flow, where $T_{02} > T_{01}$ and $P_{01} > P_{02}$ always but condition $M_2 > M_1$ and $P_2 > P_1$ need no to be true always.

45. **[Ans. A, C, D]**

46. **[Ans. A, B, C]**

47. **[Ans. A, C, D]**

$$P_{cr} = \frac{n^2 \pi^2 EI}{L_{eq}^2}$$

Depends on

- Boundary conditions $\Rightarrow L_{eq}$
- Flexural rigidity $\Rightarrow EI$
- And on density as

$$I_{min} = (Area)k^2 \ (\ k = \text{radius of gyration})$$

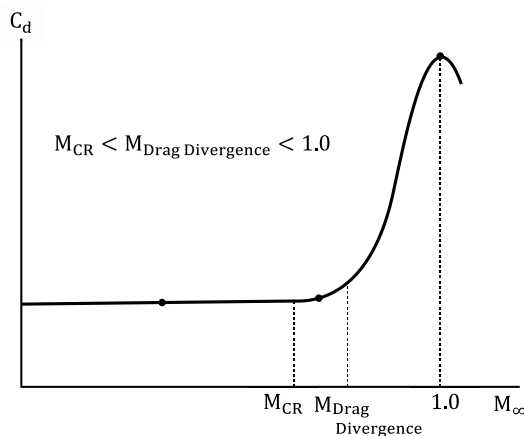$$\Rightarrow k = \sqrt{\frac{I_{min}}{A}} \quad (\text{Where } A \propto \rho)$$

48. **[Ans. *] Range: 1.1 to 1.3**

Given, $\dfrac{d_i}{d_o} = 0.5 \Rightarrow \dfrac{r_i}{r_o} = 0.5$

$t = r_o - r_i$

$$J_{exact} = \frac{\pi}{32} (d_0^4 - d_i^4)$$

$$= \frac{\pi}{2} (r_0^4 - r_i^4)$$

$$= \frac{\pi}{2} (r_o^2 - r_i^2)(r_o^2 + r_i^2)$$

$$= \frac{\pi}{2} [r_o^2 + (0.5 r_o)^2] [r_o + (0.5 r_o)] \underbrace{(r_o - 0.5r_o)}_{t}$$

$$= \frac{\pi}{2}(0.25 r_0^2 + r_0^2)(1.5r_0)t$$

$$J_{exact} = 2.943 \ r_0^3 t$$

$$J_{approx} = 2\pi r_m^3 t \ \left[\text{where } r_m = \frac{r_o + r_1}{2}\right]$$

$$= 2\pi \left(\frac{1.5r_0}{2}\right)^3 t$$
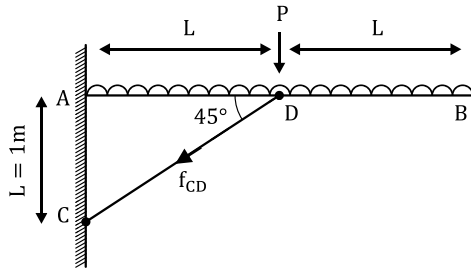
$$= 2.649 \ r_0^3 t$$

$$\tau_{max} = \frac{T}{J} \ r_{max}$$

$$\therefore \frac{\tau_{max}}{(\tau_{max})_{app}} = \left(\frac{J_{approx}}{J_{exact}}\right) \frac{r_{max}}{(r_{max})_{app}}$$

$$= \left(\frac{2.649 \ r_0^3 t}{2.943 \ r_0^3 t}\right) \left(\frac{r_o}{0.75 \ r_o}\right)$$

$$= 1.2$$

49. **[Ans. *] Range: 10 to 10**

Applying a virtual load (P) at 'D'

$$\sum M_A = 0$$

$$\Rightarrow w(L)2(L) = P(L) + \left(\frac{F_{CD}}{\sqrt{2}}\right)L$$

$$\Rightarrow F_{CD} = 2\sqrt{2}wL - P\sqrt{2}$$

Deflection at D along P is given by

$$\delta_D = \left[\frac{\partial U_{total}}{\partial P}\right]_{P=0}$$

$$U_{Beam} = 0 \Rightarrow rigid$$

$$U_{CD} = \frac{(F_{CD})^2 (L_{CD})}{2AE} = \frac{\left(2\sqrt{2}wL - \sqrt{2}P\right)^2}{2\left(\frac{AE}{L}\right)_{CD}}$$

$$\left(\frac{AE}{L}\right)_{CD} = 40 \text{ N/mm}$$

$$\Rightarrow U_{CD} = \frac{8w^2 + L^2 + 2P^2 - 8wLP}{2\left(\frac{AE}{L}\right)_{CD}}$$
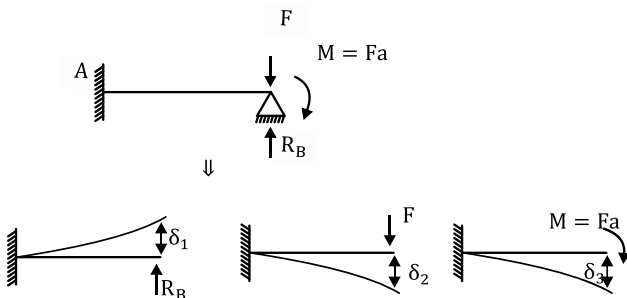
$$\therefore \delta_D = \frac{d}{dP}(U_{CD})$$

$$= \frac{4P - 8wL}{2\left(\frac{AE}{L}\right)_{CD}}$$

$$\Rightarrow \delta_D = \frac{8 \times 100 \times 10^{-3} \times 1}{2 \times 40}$$

$$\Rightarrow \delta_D = 10 \text{ mm}$$

50. **[Ans. *] Range: 0.5 to 0.5**

Given problem can be transformed to

$$\therefore (\delta_B)_{net} = 0 \Rightarrow \delta_1 - \delta_2 - \delta_3 = 0$$

$$\Rightarrow \frac{R_B (a)^3}{3EI} - \frac{F(a)^3}{3EI} - \frac{Fa^3}{2EI} = 0$$

$$\Rightarrow R_B = 0.5 \, Fa$$

$$\therefore \alpha = 0.5$$

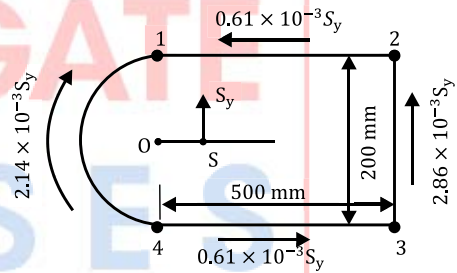51. **[Ans. *] Range: 2.80 to 2.86**

$$n = 2$$

$$\delta = \frac{1}{n} \ln \frac{x_o}{x_n}$$

$$\therefore \delta = \frac{1}{2} \ln \frac{x_o}{x_2} = 2\pi\zeta$$

$$\Rightarrow \frac{x_0}{x_2} = e^{4\pi\zeta}$$

$$\Rightarrow x_2 = \frac{10}{e^{0.4\pi}} = 2.84 \text{ cm}$$

52. **[Ans. *] Range: 196 to 198**

In the given figure, 1-4 is not a semicircle.

Now balancing moment about 'O'.

$$\Rightarrow S_y \times OS = 2 \times 0.61 \times 10^{-3} \times \delta_y \times 500$$
$$\times 100$$
$$+ 2.86 \times 10^{-3} \times \delta_y \times 200$$
$$\times 500 - 2 \times (SF)_{14} \int dA$$

$$\Rightarrow OS = 2 \times 0.61 \times 10^{-3} \times 500 \times 100$$
$$+ 2.86 \times 10^{-3} \times 200 \times 500$$
$$- 2 \times 2.14$$
$$\times 10^{-3}(135000$$
$$- 500 \times 200)$$

$$\Rightarrow OS = 197.2 \text{ mm}$$

53. **[Ans. *] Range: 3.40 to 3.50**

$$\sigma_1 = \text{hoop stress} = \frac{Pd}{2t} = 100 \, P$$

$\sigma_2 = \dfrac{\sigma_1}{2} = 50 \text{ P(Longitudinal)}$

From Von mises yield criterion

$\dfrac{\sigma_{yt}}{FOS} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2} \quad [\because \sigma_3 = 0 \;](\text{radial})$

$\Rightarrow \dfrac{300}{1} = \sqrt{(100P)^2 + (50P)^2 - (100P)(50P)}$

$\Rightarrow P = 3.46 \text{ MPa}$

54. **[Ans. *] Range: 0.24 to 0.26**

$x^2 \dfrac{d^2 y}{dx^2} + 4x \dfrac{dy}{dx} + 2y = 0$

$\Rightarrow D(D-1)y + 4Dy + 2y = 0$

$\Rightarrow [D(D-1) + 4D + 2]y = 0$

$\Rightarrow D^2 + 3D + 2 = 0$

$\Rightarrow (D+2)(D+1) = 0 \;\; \Rightarrow D = -2, -1$

$\therefore y = C_1 e^{-2t} + C_2 e^{-t}$

Now, $t = \ln x$

$\Rightarrow y = C_1 x^{-2} + C_2 x^{-1}$

Now using boundary conditions

$C_1 = -1$ and $C_2 = 1$

and $y(x = 2) = 0.25$

55. **[Ans. *] Range: 1.24 to 1.26**

Given, $\quad \phi = \dfrac{\dot{V}}{\omega^p D^q}$

From Dimensional analysis

$\dot{V} = L^3 T^{-1}, \omega = T^{-1}, D = L$

$\therefore \phi = \dfrac{\dot{V}}{\omega D^3} \quad [p = 1 \text{ and } q = 3]$

Similiarly, $\phi' = \dfrac{\dot{V}}{(1.25\omega)D^3}$

Given, $C_p = a\phi^2 = \dfrac{a\dot{V}^2}{\omega^2 D^6} = \dfrac{P}{\rho\omega^3 D^5} \ldots \text{①}$

$C_p' = a\phi'^2 = \dfrac{a\dot{V}^2}{(1.25w)^2 D^6} = \dfrac{P'}{\rho(1.25w)^3 D^5} \ldots \text{②}$

Now ① $\div$ ②

$\Rightarrow P' = 1.25\, P \;\; \therefore \;\; \alpha = 1.25$

56. **[Ans. *] Range: 0.55 to 0.57**

$\alpha_{L=0} = -1.1°$

For thin airfoil, $a = 2\pi/\text{rad}$
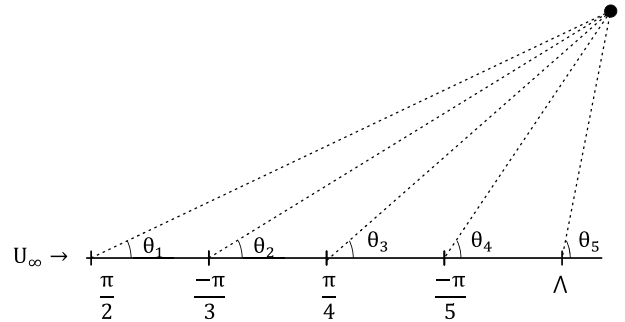
Given, $\alpha = 4°$

$\therefore C_l = a(\alpha - \alpha_{L=0})$

$= 2\pi(4 + 1.1)\dfrac{\pi}{180}$

$C_l = 0.559$

57. **[Ans. *] Range: -0.69 to -0.67**

$\therefore \psi = U_\infty r \sin\theta + \dfrac{\Lambda_1 \theta_1}{2\pi} + \dfrac{\Lambda_2 \theta_2}{2\pi} + \dfrac{\Lambda_3 \theta_3}{2\pi} + \dfrac{\Lambda_4 \theta_4}{2\pi}$
$\qquad\qquad + \dfrac{\Lambda_5 \theta_5}{2\pi}$

At stagnation point,

$\psi = 0$ and $\theta = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \pi$

$\therefore \Lambda = -0.68$

58. **[Ans. *] Range: 12.61 to 12.81**

$\vec{\zeta} = \nabla \times \vec{V} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ u & v & w \end{vmatrix}$

$\vec{\zeta} = \hat{\imath}\left(\dfrac{\partial w}{\partial y} - \dfrac{\partial v}{\partial z}\right) - \hat{\jmath}\left(\dfrac{\partial w}{\partial x} - \dfrac{\partial u}{\partial z}\right) + \hat{k}\left(\dfrac{\partial v}{\partial x} - \dfrac{\partial u}{\partial y}\right)$

$\Rightarrow \vec{\zeta} = 0.7\hat{\imath} + 1.8\hat{\jmath} + 3\hat{k}$

Enstrophy $(E) = \left|\vec{\zeta}\right|^2 = 0.7^2 + 1.8^2 + 3^2$

$\qquad\qquad = 12.73$

59. **[Ans. *] Range: 2615 to 2625**

$L = W\cos\gamma$

$T = D + W\sin\gamma$

$= \left(C_D \times \dfrac{1}{2}\rho v^2 S\right) + W\sin\gamma$
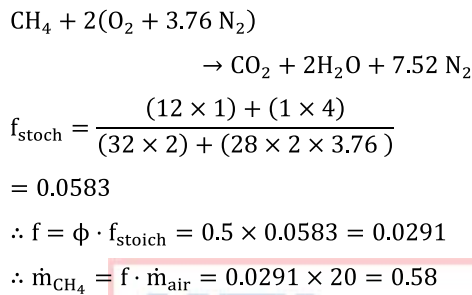
$= 1820 + 798.66$

$= 2618.67 \text{ N}$

60. **[Ans. *] Range: 190 to 195**

$$V^* = \sqrt{\frac{2n_{max} \times W}{\rho \delta C_{L_{max}}}}$$

$$= \sqrt{\frac{2 \times 7 \times 6500}{1.23 \times 2}}$$

$$= 192.33 \text{ m/s}$$

61. **[Ans. *] Range: 0.57 to 0.60**

$$CH_4 + 2(O_2 + 3.76\,N_2)$$
$$\rightarrow CO_2 + 2H_2O + 7.52\,N_2$$

$$f_{stoch} = \frac{(12 \times 1) + (1 \times 4)}{(32 \times 2) + (28 \times 2 \times 3.76\,)}$$

$$= 0.0583$$

$$\therefore f = \phi \cdot f_{stoich} = 0.5 \times 0.0583 = 0.0291$$

$$\therefore \dot{m}_{CH_4} = f \cdot \dot{m}_{air} = 0.0291 \times 20 = 0.58$$

62. **[Ans. *] Range: 4.9 to 5.1**

$$V_{escape} = \sqrt{\frac{2GM}{R}}$$

$$= \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6.4169 \times 10^{23}}{3390}}$$

$$= 5.024 \text{ km/s}$$

63. **[Ans. *] Range: 260 to 300**

Time period $(T) = \dfrac{2\pi a}{V}$ where $a = R + h$

ans $V = \sqrt{\dfrac{GM}{R+h}}$

$$\Rightarrow 90 \times 60 = \frac{2\pi(R+h)}{\sqrt{\dfrac{GM}{R+h}}}$$

$$\Rightarrow h = 284 \text{ km}$$

64. **[Ans. *] Range: 15948 to 16048**

We know,

$$W_c = \sigma U_2^2 \quad \text{also } W_c = C_p(\Delta T_O)$$

$$= \sigma \left(\frac{\pi d_2 N}{60}\right)^2$$

Now to find ΔT_o

$$\eta_c = \frac{T_{01}\left(\pi_c^{\frac{\gamma-1}{\gamma}} - 1\right)}{\Delta T_o} = \frac{\pi_c^{\frac{\gamma-1}{\gamma}} - 1}{\pi_c^{\frac{\gamma-1}{\eta_p \gamma}} - 1}$$

$$\Delta T_O = 231.5 \text{ k}$$

$$\therefore N = \sqrt{\frac{C_p(\Delta T_o)}{\sigma}}\left(\frac{60}{\pi d_2}\right)$$
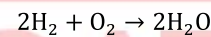
$$\Rightarrow N = 15999 \text{ RPM}$$

65. **[Ans. *] Range: 16 to 16**

Given,

$$\dot{m}_{H_2} = 32 \text{ kg/s}$$

$$\frac{\dot{m}_{O_2}}{\dot{m}_{H_2}} = 8$$

$$\dot{m}_{O_2} = 256 \text{ kg/s}$$

$$2H_2 + O_2 \rightarrow 2H_2O$$

2kmol : 1 kmol : : 2kmol

We know,

$$H_2 = 2 \text{ kg/mol}$$

$$O_2 = 32 \text{ kg/mol}$$

Now,

32 kg/s of $H_2 = \frac{32}{2}$ kmol/s = 16 kmol/s

256 kg/s of $O_2 = \frac{256}{32}$ kmol/s = 8 kmol/s

Since,

2 kmol H_2 and 1 kmol O_2 gives 2 kmol H_2O

16 kmol H_2 and 8 kmol O_2 gives 16 kmol H_2O

$\therefore$ Rate of $H_2O = 16$ kmol/s