**2007**
**AE: Aerospace Engineering**

Duration: Three Hours | Maximum Marks: 150

**Read the following instructions carefully**

1. This question paper contains 85 objective type questions. Q. 1 to Q. 20 carry **one** mark each and Q. 21 to Q. 85 carry **two** marks each.
2. Attempt all the questions.
3. Questions must be answered on **O**bjective **R**esponse **S**heet (**ORS**) by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the **ORS. Each question has only one correct answer.** In case you wish to change an answer, erase the old answer completely.
4. Wrong answers will carry NEGATIVE marks. In Q.1 to Q.20, **0.25** marks will be deducted for each wrong answer. In Q.21 to Q.76, Q.78, Q.80, Q.82 and in Q.84, **0.5** marks will be deducted for each wrong answer. However, there is no negative marking in Q.77, Q.79, Q.81, Q.83 and in Q.85. More than one answer bubbled against a question will be taken as an incorrect response. Unattempted questions will not carry any marks.
5. Write your registration number, your name and nae of the examination centre at the specified locations on the right half of the **ORS.**
6. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.
7. Calculator is allowed in the examination hall.
8. Charts, graph sheets or tables are NOT allowed in the examination hall.
9. Rough work can be done on the question paper itself. Additionally blank pages are given at the end of the question paper for rough work.
10. This question paper contains **24** printed pages including pages for rough work. Please check all pages and report, if there is any discrepancy.

**Q. 1 - Q. 20 carry one mark each)**

1. Which one of the following engines should be used by a subsonic passenger transport airplane for minimum specific fuel consumption?

   (a) Turbojet engine with afterburner
   (b) Turbofan engine
   (c) Ramjet engine
   (d) Scramjet engine

2. A spring-mass-damper system with a mass of 1 kg is found to have a damping ratio of 0.2 and a natural frequency of 5 rad/s. The damping of the system is given by

   (a) 2 Ns/m (b) 2 N/s (c) 0.2 kg/s (d) 0.2 N/m

3. If $f(\theta)=\begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}, then$ f($\alpha$) f($\beta$) =

   (a) $f(\alpha/\beta)$
   (b) $f(\alpha+\beta)$
   (c) $f(\alpha-\beta)$
   (d) $2\times 2$ zero matrix

4. An artificial satellite remains in orbit and does not fall to the earth because

   (a) the centrifugal force acting on it balance the gravitational attraction
   (b) the on-board rocket motors provide continuous boost to keep it in orbit
   (c) its transverse velocity keeps it from hitting the earth although it falls continuously
   (d) due to its high speed it derives sufficiant lift from the rarefied atmosphere

5. The Euler iteration formula for numerically integrating a first order nonlinear differential equation of form $x = f(x)$, with a constant step size of $\Delta t$ is

   (a) $x_{k+1} = x_k - \Delta t \times f(x_k)$
   (b) $x_{k+1} = x_k + \left(\Delta t^2/2\right) \times f(x_k)$
   (c) $x_{k+1} = x_k - (1/\Delta t) \times f(x_k)$
   (d) $x_{k+1} = x_k + \Delta t \times f(x_k)$

6. The number of natural frequencies of an elastic beam with cantilever boundary conditions is

   (a) 1 (b) 3 (c) 1000 (d) Infinite

7. For maximum range of a glider, which of the following conditions is true?

   (a) Lift to drag ratio is maximum
   (b) Rate of descent is minimum
   (c) Descent angle is maximum
   (d) Lift to weight ratio is maximum

8. An airplane with a larger wing as compared to a smaller wing will necessarily have
   (a) More longitudinal static stability
   (b) Less longitudinal static stability
   (c) Same longitudinal static stability
   (d) More longitudinal static stability for an aft tail airplane if aerodynamic center of the larger wing is behind the center of gravity of the airplane

9. The minimum value of$J(x) = x^2 - 7x + 30$ occurs at
   (a) $x = 7/2$
   (b) $x = 7/30$
   (c) $x = 30/7$
   (d) $x = 30$

10. Two airplanes are identical except for the location of the wing. The longitudinal static stability of the airplane with low wing configuration will be
    (a) More than the airplane with high wing configuration
    (b) less than the airplane with high wing configuration
    (c) same as the airplane with high wing configuration
    (d) more if elevator is deflected

11. For a fixed centre of gravity location of an airplane, when the propeller is mounted on the nose of the fuselage
    (a) longitude static stability increases
    (b) longitude static stability decreases
    (c) longitude static stability remains same
    (d) longitude static stability is maximum

12. Let an airplane in a steady level flight be trimmed at a certain spee(D) A level and steady flight at a higher speed could be achived by changing
    (a) Engine throttle only
    (b) Elevator only
    (c) Throttle and elevator together
    (d) Rudder only

13. For a plane strain problem in the $x - y$ plane, in general, the non-zero stress terms are
    (a) $\sigma_{xx}, \sigma_{yy}, \sigma_{zz}, \sigma_{xy}$
    (b) $\sigma_{xx}, \sigma_{yy}, \sigma_{xy}$
    (c) $\sigma_{xx}, \sigma_{yy}, \sigma_{xy}, \sigma_{xz}$
    (d) $\sigma_{xx}, \sigma_{yy}, \sigma_{xy}, \sigma_{zz}$

14. For an elastic anisotropic solid, the number of independent elastic constants in its constitutive equations is

(a) 2 (b) 9 (c) 21 (d) 36

15. Total pressure at a point is defined as the pressure when the flow is brought to rest

    (a) Adiabatically
    (b) Isentropically
    (c) Isothermally
    (d) Isobarically

16. The drag divergence Mach number of an airfoil

    (a) Is a fixed number for a given airfoil
    (b) Is always higher than the critical Mach number
    (c) Is equal to the critical Mach number at zero angle of attack
    (d) Is the Mach number at which a shock wave first appears on the airfoil

17. On which one of the following thermodynamic cycles does an ideal ramjet operate?

    (a) The Rankine cycle
    (b) The Brayton cycle
    (c) The Carnot cycle
    (d) The Diesel cycle

18. Across a normal shock

    (a) both temperature and total pressure decreases
    (b) both temperature and total pressure remains constant
    (c) total pressure remain constant but total temperature decreases
    (d) total temperature remains constant but total pressure decreases

19. The Joukowski airfoil is studied in aerodynamics because

    (a) It is used in many aircraft
    (b) It is easily transformed into a circle, mathematically
    (c) It has a simple geometry
    (d) It has the highest lift curve slope among all airfoils

20. One of the criteria for high-speed airplanes is that the critical Mach number should be as high as possible. Therefore, high-speed subsonic airplanes are usually designed with

    (a) Thick airfoils
    (b) Thin airfoils
    (c) Laminar flow airfoils
    (d) Diamond airfoils

**Q. 21 - Q. 75 carry two marks each**

21. Two identical earth satellites $A$ and $B$ are in circular orbits at altitudes $h_A$ and $h_B$ above the earth's surface respectively, with $h_A > h_B$. If $E$ denotes the total mechanical energy, $T$ the kinetic energy and $V$ the gravitational potential energy of a satellite, then:

    (a) $E_A > E_B$ and $V_A < V_B$
    (b) $E_A > E_B$ and $T_A > T_B$
    (c) $E_A < E_B$ and $T_A > T_B$
    (d) $E_A > E_B$ and $T_A < T_B$

22. Let $P$ and $Q$ be two square matrices of same size. Consider the following statements

    (i) $PQ = 0$ implies $P = 0$ or $Q = 0$ or both
    (ii) $PQ = I$ implies $QP = I$
    (iii) $(P + Q)^2 = P^2 + 2PQ + Q^2$
    (iv) $(P - q)^2 = P^2 - 2PQ + Q^2$

    where I is identity matrix. Whinch of the folliwing statement is correct?

    (a) Both (i) and (ii) are true
    (b) (i) is true but (ii) is false
    (c) (i) is false but (ii) is true
    (d) Both (i) and (ii) are false

23. A 1 kg mass attached to a spring elongates it by 16 mm. The mass is then pulled from its equilibrium position by 10 mm and released from rest. Assuming the acceleration due to gravity of $9.81m/s^2$, the response of the mass in mm is given by:

    (a) $x = \cos 4.76\,t$
    (b) $x = \sin 4.76\,t$
    (c) $x = \sin 16\,t$
    (d) $x = 10 \cos 16\,t$

24. The earth's radius is $6.37\times10^6$ m and the acceleration due to gravity on its surface is $9.81\ \mathrm{m/s^2}$. A satellite is in a circular orbit at a height of $6.30 \times 10^6$ m above the earth's surface. The minimum additional speed it needs to escape from the earth's gravitational field is

    (a) $3.66 \times 10^3$ m/s (b) $3.12 \times 10^3$ m/s (c) $3.27 \times 10^3$ m/s (d) $3.43 \times 10^3$ m/s

25. Shown in the figure below is a model of an Euler-Bernoulli beam made up of two materials subjected to pure bending moment $M$. The Young's modulus of material A and B are $E_A$ and $E_B$, respectively. The sectional moment of area, about the neutral axis, of the cross-sectional areas made of materials A and B, are $I_A$ and $I_B$, respectively. The radius of curvature $\rho$ of the flexural deflection of this composite beam to the bending moment $M$ is then

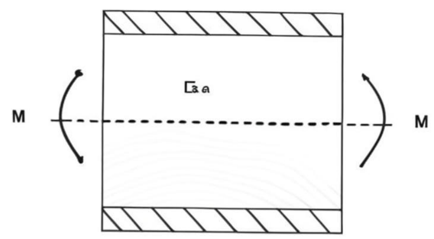


Figure 1

(a) $\rho = \frac{E_A I_A + E_B I_B}{M}$

(b) $\rho = \frac{E_A I_B + E_B I_A}{M}$

(c) $\rho = \frac{M}{E_A I_A + E_B I_B}$

(d) $\rho = \frac{E_A I_A + E_B I_B}{M^2}$

26. Two pipes with constant sections but different diameters carry water at the same volume flow rate. The Reynolds number, based on the pipe diameter, is

(a) The same in both pipes
(b) Is larger in the narrower pipe
(c) Is smaller in the narrower pipe
(d) Depends on the material of the pipes

27. Two airfoils of the same family are operating at the same angle of attack. The dimensions of one airfoil are twice as large as the other one. The ratio of the minimum pressure coefficient of the larger airfoil to the minimum pressure coefficient of the smaller airfoil is

(a) 4.0 (b) 2.0 (c) 1.0 (d) 0.5

28. Wing A has a constant chord $c$ and span $b$. Wing B is identical but has a span $4b$. When both wings are operating at the same geometric angle of attack at subsonic speed, then:

(a) Wings A and B produce the same lift coefficient
(b) Wing A produces a smaller lift coefficient than wing B
(c) Wing A produces a greater lift coefficient than wing B
(d) The freestream Mach number decides which wing produces the greater lift coefficient

29. A spring-mass-damper system is excited by a force $F_0 \sin \omega t$. The amplitude at resonance is measured to be 1 cm. At half the resonance frequency, the amplitude is 0.5 cm. The damping ratio of the system is

(a) 0.1026 (b) 0.3242 (c) 0.7211 (d) 0.1936

30. 30] The eigenvalues of the matrix, A = $\begin{bmatrix} 2 & 10 & 3 \end{bmatrix}$ are

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

31. The eigenvalues of the matrix, $A^{-1}$, where A = $\begin{bmatrix} 2 & 10 & 3 \end{bmatrix}$, are

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

32. The radius of the earth is $6.37 \times 10^4 m$ and the acceleration due to gravity at its surface is $9.81 m/s^2$. A satellite is in circular orbit at a height of $35.9 \times 10^6 m$ above the earth's surface. This orbit is inclined at 10.5 degrees to the equator. The velocity change needed to make the orbit equatorial is:

(a) 561 m/s at 84.75 degrees to the initial direction
(b) 561 m/s at 95.25 degrees to the initial direction
(c) 281 m/s at 84.75 degrees to the initial direction
(d) 281 m/s at 95.25 degrees to the initial direction

33. A piston-prop airplane having propeller efficiency, $\eta_p = 0.8$ and weighing 73108 N could achieve maximum climb rate of 15 m/s at flight speed of 50 m/s. The excess Brake Power (BP) at the above flight condition will be

(a) 1700 kW (b) 2100 kW (c) 1371 kW (d) 6125 kW

34. An airplane model with a symmetric airfoil was tested in a wind tunnel. $C_{m0}$ ($C_m$ at angle of attack, $\alpha = 0$) was estimated to be 0.08 and 0 respectively for elevator settings ($\delta e$) of 5 degrees up and 5 degrees down. The estimated value of the elevator control power $\left(\frac{\partial C_m}{\partial \delta e}\right)$ of the model will be

(a) 0.07 per deg (b) -1.065 per deg (c) -0.008 per deg (d) -0.762 per deg

35. The lateral-directional characteristic equation for an airplane gave the following set of roots: $\lambda_1 = -0.6, \lambda_2 = -0.002, \lambda_{3,4} = -0.06 \pm j1.5$, where $j = \sqrt{-1}$. The damping ratio corresponding to the Dutch-roll mode will be

(a) 0.04 (b) 0.66 (c) 0.35 (d) 0.18

36. An airplane is flying at an altitude of 10 $km$ above sea level. Outside air temperature and density at 10 $km$ altitude are 223 $K$ and 0.413 $kg/m^3$ respectively. The airspeed indicator shows 60 $m/s$. Density of air at sea level is 1.225 $kg/m^3$ and gas constant $R = 288\ J/kg/K$. The stagnation pressure $P_0$ measured by the Pitot tube mounted on the wing tip will be:

(a) $3.5 \times 10^4$ $N/m^2$ (b) $2.0 \times 10^4$ $N/m^2$ (c) $2.87 \times 10^4$ $N/m^2$ (d) $0.6 \times 10^4$ $N/m^2$

37. If the center of gravity of an airplane is moved forward toward the nose of the airplane, the $C_{Lmax}$ (maximum value of the lift coefficient) value for which the airplane can be trimmed ($C_m = 0$) will

(a) decreases
(b) increases
(c) remains same
(d) depend upon rudder deflection

38. If the contribution of only the horizontal tail of an airplane was considered for estimating $\frac{\partial C_m}{\partial \alpha}$, and if the tail moment arm $l_t$ was doubled, then how many times the original value would the new $\frac{\partial C_m}{\partial \alpha}$ become?

(a) Two times (b) Three times (c) 1.414 times (d) 1.732 times

39. If the vertical tail of an airplane is inverted and put below the horizontal tail, then the contribution to roll derivative, $\frac{\partial C_l}{\partial \beta}$, will be

(a) Negative (b) Positive (c) Zero (d) Imaginary

40. Let a system of linear equations be as follows:

$$x - y + 2z = 0$$
$$2x + 3y - z = 0$$
$$2x - 2y + 4z = 0$$

This system of equations has

(a) No non-trivial solution
(b) Infinite number of non-trivial solutions
(c) An unique non-trivial solution
(d) Two non-trivial solutions

41. A turbulent boundary layer remains attached over a longer distance on the upper surface of an airfoil than does a laminar boundary layer, because

(a) The turbulent boundary layer is more energetic and hence can overcome the adverse pressure gradient better
(b) The laminar boundary layer is more energetic
(c) The turbulent boundary layer has a lower skin friction
(d) The laminar boundary layer has a higher skin friction

42. The laminar boundary layer on a flat plate held parallel to the freestream in 5 *mm* thick at a point 0.2 *m* downstream of the leading edge. The thickness of the boundary layer at a point 0.8 *m* downstream of the leading edge will be

(a) 20 $mm$ (b) 10 $mm$ (c) 5 $mm$ (d) 2.5 $mm$

43. If horizontal tail area is increased while the elevator to horizontal tail area ratio is kept same, then

    (a) Both longitudinal static stability and elevator control power will increase
    (b) Only longitudinal static stability will increase
    (c) Only elevator control power will increase
    (d) Neither stability nor control power changes

44. A circular shaft is made-up of two materials A and (B) The inner core is made-up of material A with diameter $d_A$, torsion constant $J_A$, and shear modulus $G_A$. The outer sleeve is made-up of material B with diameter $d_B$, torsion constant $J_B$, and shear modulus $G_B$. The composite shaft is of length $L$ and is subjected to pure torsion moment $T$. The torsional stiffness, $\frac{T}{\phi}$, where $\phi$ is the angle of twist, of this composite shaft is then

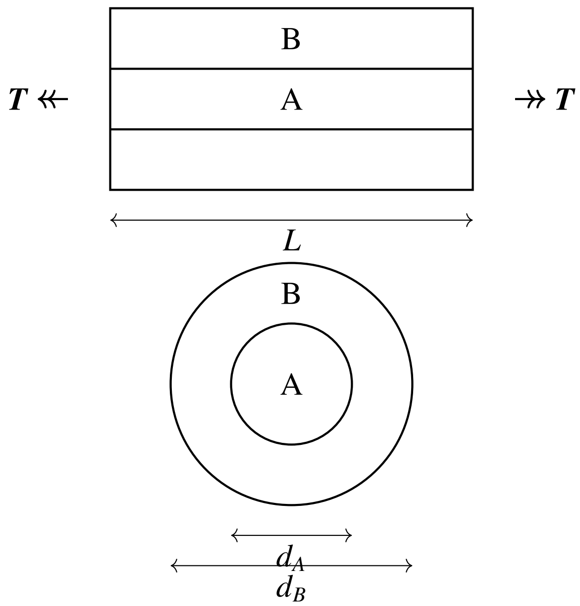


Figure 2

    (a) $\frac{\left(\frac{G_A J_A}{L} \frac{G_B J_B}{L}\right)}{\left(\frac{G_A J_A}{L} + \frac{G_B J_B}{L}\right)}$
    (b) $\frac{G_A J_A}{L} + \frac{G_B J_B}{L}$
    (c) $\frac{(G_A + G_B)(J_A + J_B)}{L}$
    (d) $\frac{G_A J_A}{L} + \frac{G_B J_A}{L}$

45. Air enters through the eye of a centrifugal compressor with a stagnation temperature 300 K and exits the compressor with a stagnation temperature 424 K. If the isentropic efficiency of the compressor is 0.81 and the ratio of specific heats of the flowing gas (assumed as constant) is 1.4, then the pressure ratio across the compressor is

(a) 2.75 (b) 5.60 (c) 65.00 (d) 228.00

46. The boundary conditions for an Euler-Bernoulli column are given in column X and the critical buckling loads are given in column Y. Match the boundary condition of the column to its corresponding buckling loa(D) $P_{\sigma}$ is the critical buckling load, $E$ is the Young's modulus of the column material, $I$ its sectional moment of area, and $L$ is the length of the column.

(a) X1-Y3, X2-Y4, X3-Y1, X4-Y2
(b) X1-Y1, X2-Y4, X3-Y3, X4-Y2
(c) X1-Y3, X2-Y2, X3-Y1, X4-Y4
(d) X1-Y1, X2-Y2, X3-Y3, X4-Y4

47. For an impulse turbine with identical stages, the hot gas existe from the stator blades at the mean blade height at an angle of 70 degrees with the axis of the turbine. If the absolute intel blade is 37 degrees, then the absolute exit blade angle with the axis of the turbine at the mean blade height of the rotors blades is

(a) 33 degrees (b) 37 degrees (c) 53 degrees (d) 53.5 degrees

48. Which one of the following materials should be selected to design an axial flow turbine operating at high temperatures?

(a) Steel alloy
(b) Titanium alloy
(c) Nickel alloy
(d) Aluminum alloy

49. Which one of the following statements is true?

(a) The isentropic efficiency of a compressor is constant throughout the compressor
(b) Flow separation problems are more critical for the axial compressors than for the centrifugal compressors
(c) The pressure ratio of a centrifugal compressor approaches zero as the compressor mass flow rate approaches zero
(d) Centrifugal compressors are always designed with multiple stages

50. An athlete starts running with a speed $V_0$. Subsequently, his speed decreases by an amount that is proportional to the distance that he has already covere(D) The distance covered will be

(a) Linear in time
(b) Quadratic in time
(c) Exponential in time

(d) Logarithmic in time

51. The on-board rocket motor of a satellite of initial mass 2000 kg provides a specific impulse of 280 seconds. If this motor is fired to give a speed increment of 500 m/s along the direction of motion, the mass of propellant consumed is

    (a) 685 $kg$
    (b) 333 $kg$
    (c) 200 $kg$
    (d) 167 $kg$

52. Combustion between fuel (octane) and oxidizer (air) occurs inside a combustor with the following stoichiometric chemical reaction:

$$2C_6H_{18} + (25O_2 + 94N_2) \longrightarrow 16CO_2 + 18H_2O + 94N_2$$

The atomic weight of carbon (C), hydrogen (H), oxygen (O), and nitrogen(N) are 12, 1, 16, and 14 respectively. If the combustion takes place with the fuel to air ratio 0.028, then the equivalence ratio of the fuel-oxidizer mixture is

    (a) 0.094 (b) 0.422 (c) 0.721 (d) 2.371

53. The von Mises yield criterion or the maximum distortion energy criterion for a plane stress problem with $\sigma_1$ and $\sigma_2$ as the principal stresses in the plane, and $\sigma_T$ as the yield stress, requires

    (a) $\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2 \leq \sigma_T^2$
    (b) $|\sigma_1 - \sigma_2| \leq \sigma_T$
    (c) $|\sigma_1| \leq \sigma_T$
    (d) $|\sigma_2| \leq \sigma_T$

54. An Euler-Bernoulli beam having a rectangular cross-section, as shown in the figure, is subjected to a non-uniform bending moment along its length. $V_t = \frac{dM_p}{dx}$. The shear stress distribution $\tau_{xz}$ across its cross-section is given by

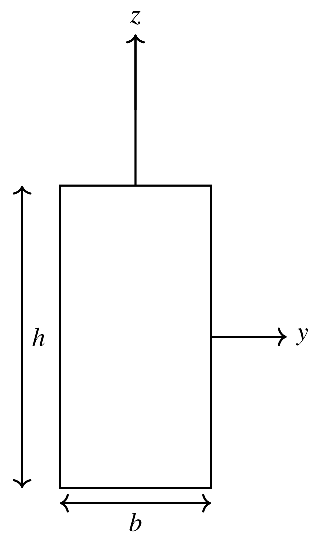


Figure 3

(a) $\tau_{xz} = \frac{V_t}{2I_y}\frac{z}{(h/2)}$

(b) $\tau_{xz} = \frac{V_t(h/2)^2}{2I_y}\left(1 - \frac{z^2}{(h/2)^2}\right)$

(c) $\tau_{xz} = \frac{V_t}{2I_y}\left(\frac{z}{(h/2)}\right)^2$

(d) $\tau_{xz} = \frac{V_t(h/2)^2}{2I_y}$

55. At a stationary point of a multi-variable function, which of the following is true?

(a) Curl of the function becomes unity

(b) Gradient of the function vanishes

(c) Divergence of the function vanishes

(d) Gradient of the function is maximum

56. In a rocket engine, the hot gas generated in the combustion chamber exits the nozzle with a mass flow rate 719 kg/sec and velocity 1794 m/s. The area of the nozzle exit section is 0.635 $\mathrm{m}^2$. If the nozzle expansion is optimum, then the thrust produced by the engine is

(a) 811 kN (b) 1290 kN (c) 1354 kN (d) 2172 kN

57. For the control volume shown in the figure below, the velocities are measured both at the upstream and the downstream ends. The flow of density $\rho$ is incompressible, two dimensional and steady. The pressure is $p_\infty$ over the entire surface of the control volume. The drag on the airfoil is given by

[tikz]standalone amsmath

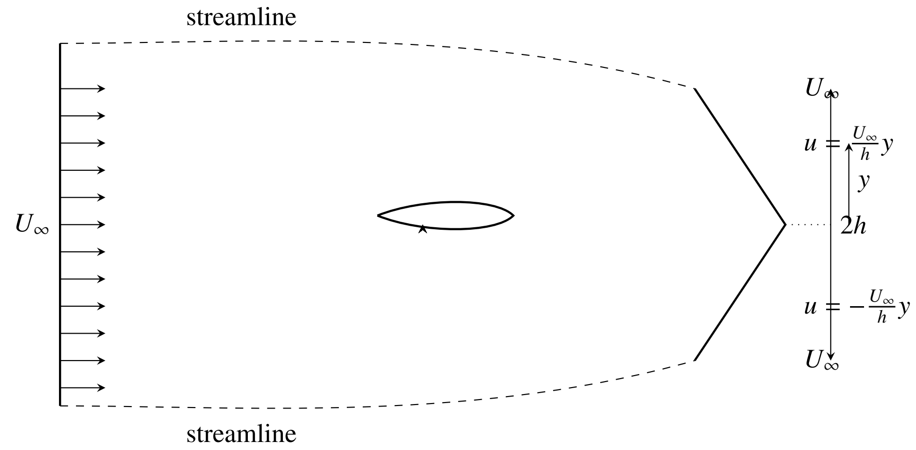


Figure 4

(a) $\frac{\rho U^2 h}{3}$

(b) 0

(c) $\frac{\rho U^2 h}{6}$

(d) $2\rho U^2 h$

58. A gas turbine engine operates with a constant area duct combustor with inlet and outlet stagnation temperatures 540 K and 1104 K respectively. Assume that the flow is one dimensional, incompressible and frictionless and that the heat addition is driving the flow inside the combustor. The pressure loss factor (stagnation pressure loss non-dimensionalized by the inlet dynamic pressure) of the combustor is

(a) 0 (b) 0.489 (c) 1.044 (d) 2.044

59. The diffuser of an airplane engine decelerates the airflow from the flight Mach number 0.85 to the compressor inlet Mach number 0.38. Assume that the ratio of specific heats is constant and equal to 1.4. If the diffuser pressure recovery ratio is 0.92, then the isentropic efficiency of the diffuser is

(a) 0.631 (b) 0.814 (c) 0.892 (d) 1.343

60. An airfoil section is known to generate lift when placed in a uniform stream of speed $U_\infty$ at an incidence $\alpha$. A biplane consisting of two sections of identical chord $c$, separated by a distance $h$ is shown in the following figure:

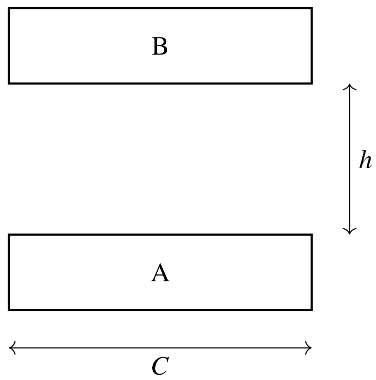


Figure 5

With regards to this biplane, which of the following statements is true?

(a) Both the airfoils experience an upwash and an increased approach velocity
(b) Both the airfoils experience a downwash and a decreased approach velocity
(c) Both the airfoils experience an upwash and airfoil A experiences a decreased approach velocity while airfoil B experiences an increased approach velocity
(d) Both the airfoils experience a downwash and airfoil A experiences an increased approach velocity while airfoil B experiences a decreased approach velocity

61. Numerical values of the integral $\int_0^1 \frac{1}{1+x^2}\, dx$ if evaluated numerically using the Trapazoidal rule with dx = 0.2 would be

(a) 1 (b) $\pi/4$ (c) 0.7837 (d) 0.2536

62. The purpose of a fuel injection system in the combustor is

(a) to accelerate the flow in the combustor
(b) to increase the stagnation pressure of the fuel-air mixture
(c) to ignite the fuel-air mixture
(d) to convert the bulk fuel into tiny droplets

63. Which of the following represents the specific impulse of a rocket engine using liquid hydrogen and liquid oxygen as propellants?

(a) 49 *sec* (b) 450 *sec* (c) 6000 *sec* (d) 40000 *sec*

64. A circular cylinder is placed in an uniform stream of ideal fluid with its axis normal to the flow. Relative to the forward stagnation point, the angular positions along the circumference where the speed along the surface of the cylinder is equal to the free stream speed are

(a) 30, 150, 210 and 330 degrees
(b) 45, 135, 225 and 315 degrees
(c) 0, 90, 180 and 270 degrees
(d) 60, 120, 240 and 300 degrees

65. The Newton-Raphson iteration formula to find a cube root of a positive number $c$ is

(a) $x_{k+1} = \frac{2x_k^3 + \sqrt[3]{c}}{3x_k^2}$
(b) $x_{k+1} = \frac{2x_k^3 - \sqrt[3]{c}}{-3x_k^2}$
(c) $x_{k+1} = \frac{2x_k^3 + c}{3x_k^2}$
(d) $x_{k+1} = \frac{x_k^3 + c}{3x_k^2}$

66. The torsion constant $J$ of a thin-walled closed tube of thickness $t$ and mean radius $r$ is given by

(a) $J = 2\pi r t^3$ (b) $J = 2\pi r^3 t$ (c) $J = 2\pi r^2 t^2$ (d) $J = 2\pi r^4$

67. An aerospace system shown in the following figure is designed in such a way that the expansion generated at A is completely absorbed by wall B for $p_1 = p_d$, where $p_d$ corresponds to the design condition.

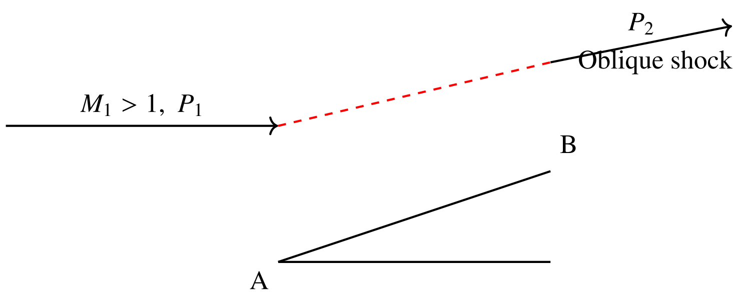


Figure 6

Figure 7

For $p_1 > p_e$ which of the following statements is NOT true?

(a) For $p_1 < p_d$, the expansion fan from A gets reflected from B as a compression wave
(b) For $p_1 > p_d$, the expansion fan from A gets reflected from B as an expansion wave
(c) For $p_1 < p_d$, the expansion fan from A gets reflected from B as an expansion wave
(d) For $p_1 > p_d$, B always sees an expansion

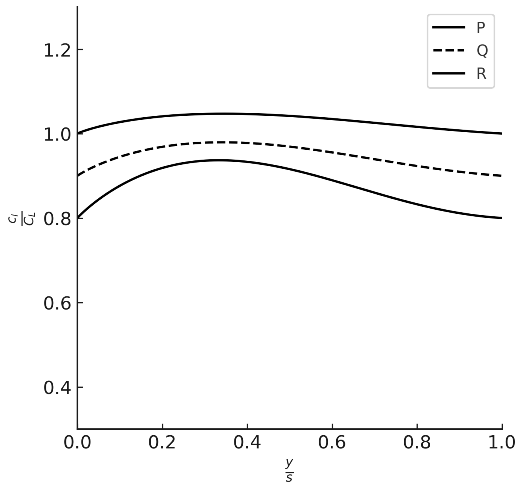


Figure 8

68. The span-wise lift distribution for three wings is shown in the following figure:

    In the above figure, $c_l$ refers to the section lift coefficient, $C_L$ refers to the lift coefficient of the wing, $y$ is the coordinate along the span and $s$ is the span of the wing. A designer prefers to use a wing for which the stall begins at the root. Which of the wings will he choose?

    (a) P (b) Q (c) R (d) None

69. $\lim_{x \to 0} \frac{\sin x}{e^4 x} =$

    (a) 10 (b) 0 (c) 1 (d) $\infty$

70. Let a dynamical system be described by the differential equation $2\frac{dx}{dt} + \cos x = 0$. Which of the following differential equations describes this system in a close approximation sense for small perturbation about $x = \pi/4$?

    (a) $2\frac{dx}{dt} + \sin x = 0$
    (b) $2\frac{dx}{dt} - \frac{1}{\sqrt{2}}x = 0$
    (c) $\frac{dx}{dt} + \cos x = 0$
    (d) $\frac{dx}{dt} + x = 0$

**Common Data Questions**

**Common Data for Questions 71, 72 & 73**: An airplane designer wants to keep longitudinal static stability margin (SM) within 5% to 15% of mean aerodynamic chor(D) A wind tunnel test of the model showed that for $\bar{X}_{CG} = 0.3$, $\frac{dC_m}{dC_L} = -0.1$. Note that the distance from the wing leading edge to the center of the gravity ($X_{CG}$) has been non-dimensionalized by dividing it with mean aerodynamic chord, $\bar{c}$, such that $\bar{X}_{CG} = X_{CG}/\bar{c}$. Note also that the relation $\frac{dC_m}{dC_L} = -SM$ holds true for this airplane.

71. The most forward location of the airplane center of gravity to fulfill designer's requirement on longitudinal static stability is

(a) $0.35\bar{c}$ (b) $0.45\bar{c}$ (c) $0.52\bar{c}$ (d) $0.67\bar{c}$

72. The most aft location of the airplane center of gravity to fulfill designer's requirement on longitudinal static stability is

    (a) $0.35\bar{c}$ (b) $0.45\bar{c}$ (c) $0.52\bar{c}$ (d) $0.67\bar{c}$

73. The center of gravity location to have $\frac{d\delta e}{dC_L} = 0$ is

    (a) $0.35\bar{c}$ (b) $0.45\bar{c}$ (c) $0.5\bar{c}$ (d) $0.4\bar{c}$

**Common Data for Questions 74 & 75**: Consider the spring mass system shown in the figure below. This system has two degrees of freedom representing the motions of the two masses.

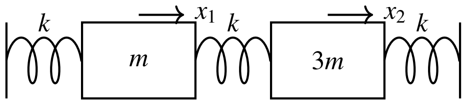


Figure 9

74. The system shows the following type of coordinate coupling
    (a) Static coupling
    (b) Dynamic coupling
    (c) Static and dynamic coupling
    (d) No coupling

75. The two natural frequencies of the system are given as

    (a) $\sqrt{\frac{4\pm\sqrt{5}k}{3m}}$ (c) $\sqrt{\frac{4\pm\sqrt{7}k}{3m}}$

    (b) $\sqrt{\frac{4\pm\sqrt{3}k}{3m}}$ (d) $\sqrt{\frac{4\pm\sqrt{11}k}{3m}}$

**Linked Answer Questions: Q. 76 to Q. 85 carry two marks each**

**Statement for Linked Answer Questions 76 & 77**: For a piston propeller airplane weighing 20000 N, the flight testing at 5 km pressure altitude in standard atmosphere gave the variation of power required versus true air speed as shown in figure below. The student forgot to label the air speed axis. The maximum climb rate at sea level was calculated to be 3.65 m/s at air density 1.225 kg/m$^3$ and 0.815 kg/m$^3$, respectively.

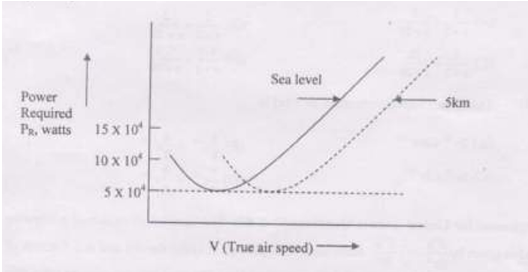


Figure 10

76. The maximum rate of climb achievable by this airplane at 5 km altitude will be

    (a) 1.65 $m/s$ (b) 0.51 $m/s$ (c) 1.43 $m/s$ (d) 3.65 $m/s$

77. If during the maximum rate of climb at 5 km altitude, the airplane was flying at an angle of attack of 4 degrees and attitude (pitch) angle of 5 degrees, what was equivalent airspeed of the airplane?

    (a) 40.2 $m/s$ (b) 63.7 $m/s$ (c) 130.3 $m/s$ (d) 20.2 $m/s$

**Statement for Linked Answer Questions 78 & 79**: A model wing of rectangular planform has a chord of 0.2 m and a span of 1.2 m. It has a symmetric airfoil section whose lift curve slope is 0.1 per degree. When this wing is mounted at 8 degrees angle of attack in a freestream of 20 m/s it is found to develop 35.3 N lift when the density of air is 1.225 kg/m$^3$.

78. The lift curve slope of this wing is

    (a) 0.10 per deg (b) 0.092 per deg (c) 0.075 per deg (d) 0.050 per deg

79. The span efficiency factor of this wing is

    (a) 1.0 (b) 0.91 (c) 0.75 (d) 0.63

**Statement for Linked Answer Questions 80 & 81**: Let $F(s) = \frac{(s+10)}{(s+2)(s+20)}$

80. The partial fraction expansion of $F(s)$ is

    (a) $\frac{1}{s+2} + \frac{1}{s+20}$ (c) $\frac{2}{s+2} + \frac{20}{s+20}$
    (b) $\frac{5}{s+2} + \frac{2}{s+20}$ (d) $\frac{4/9}{s+2} + \frac{5/9}{s+20}$

81. The inverse Laplace transform of $F(s)$ is

    (a) $2e^{-34} + 20e^{-34}$ (c) $5e^{-34} + 2e^{-34}$
    (b) $\frac{4}{9}e^{-34} + \frac{5}{9}e^{-34}$ (d) $\frac{9}{4}e^{-34} + \frac{9}{5}e^{-34}$

**Statement for Linked Answer Questions 82 & 83**: The equation of motion of a vibrating rod is given by $\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$. Here $u$ is the displacement along the rod and is a function of both position $x$ and time $t$. To find the response of the vibrating rod, we need to solve this equation using boundary conditions and initial conditions.

82. The boundary conditions needed for a rod fixed at the root ($x = 0$) and free at the tip ($x = l$) are

(a) $u(x = 0) = 0, \frac{\partial u}{\partial x}(x = l) = 0$
(b) $u(x = l) = 0, \frac{\partial u}{\partial x}(x = l) = 0$
(c) $u(x = 0) = 0, u(x = l) = 0$
(d) $\frac{\partial u}{\partial x}(x = 0) = 0, \frac{\partial u}{\partial x}(x = l) = 0$

83. The natural frequencies $\omega$ of the fixed-free rod can then be obtained using

(a) $\cos\left(\frac{\omega l}{c}\right) = 0$ (b) $\sin\left(\frac{\omega l}{c}\right) = 0$ (c) $\cos\left(\frac{\omega c}{l}\right) = 0$ (d) $\cos\left(\frac{\omega}{c}\right) = 0$

**Statement for Linked Answer Questions 84 & 85**: Air enters the compressor of a gas turbine engine with velocity 127 m/s, density 1.2 kg/m$^3$ and stagnation pressure 0.9 MPa. Air exits the compressor with velocity 139 m/s and stagnation pressure 3.15 MPa. Assume that the ratio of specific heats is constant and equal to 1.4.

84. The compressor pressure ratio is

(a) 0.22 (b) 0.28 (c) 3.50 (d) 3.90

85. If the polytropic efficiency of the compressor is 0.89, then the isentropic efficiency of the compressor is

(a) 0.613 (b) 0.869 (c) 0.89 (d) 0.98

# END OF THE QUESTION PAPER