GATE Aerospace Engineering

Sample Paper – 6

Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Aerospace Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Unless stated otherwise, take air as a perfect gas with $\gamma = 1.4$ and $R = 287$ J/kg · K, $g = g_0 = 9.81$ m/s^2, and standard Earth gravitational parameter $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Aerodynamics

Q1. An aircraft flies at a true airspeed of 170 m/s at an altitude where the static air temperature is 288 K. Taking $\gamma = 1.4$ and $R = 287$ J/kg · K, the flight Mach number is nearest to: **[1 mark]**

(A) 0.60

(B) 0.50

(C) 0.71

(D) 0.42

Q2. At a point on an airfoil the incompressible pressure coefficient is $C_{p,0} = 0.40$. The airfoil operates in a freestream of Mach number 0.60. Using the Prandtl–Glauert compressibility correction $\left(C_p = C_{p,0}/\sqrt{1 - M_\infty^2}\right)$, the corrected pressure coefficient is: **[1 mark]**

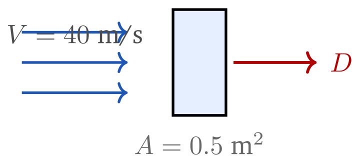
(A) 0.40

(B) 0.32

(C) 0.50

(D) 0.64

Q3. A bluff body of frontal area $0.5\ \text{m}^2$ and drag coefficient 0.40 is placed in an airstream of density $1.225\ \text{kg/m}^3$ moving at 40 m/s, as shown. The drag force on the body is: **[1 mark]**



(A) 392 N

(B) 98 N

(C) 196 N

(D) 490 N

Q4. An aircraft in steady, level flight at sea level ($\rho = 1.225\ \text{kg/m}^3$) flies at 50 m/s with a wing area of $20\ \text{m}^2$ and a lift coefficient of 0.40. The lift force generated by the wing is: **[1 mark]**

(A) 12250 N

(B) 6125 N

(C) 24500 N

(D) 3062.5 N

Q5. A finite wing operates at a lift coefficient of 0.60 with an aspect ratio of 7 and an Oswald span efficiency factor of 0.85. The zero-lift (parasite) drag coefficient of the aircraft is 0.020. The total drag coefficient is nearest to: **[1 mark]**

(A) 0.0193

(B) 0.0200

(C) 0.0592

(D) 0.0393

Q6. An aircraft has a gross weight of $30{,}000$ N and a wing planform area of 20 m^2. The wing loading of the aircraft is: **[1 mark]**

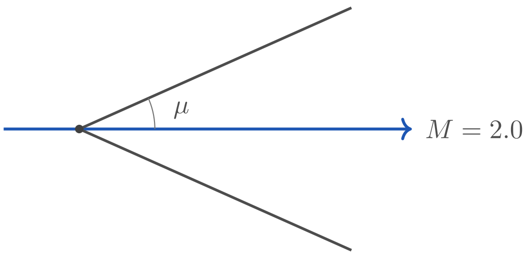
(A) 3000 N/m^2

(B) 1500 N/m^2

(C) 750 N/m^2

(D) $600{,}000$ N/m^2

Q7. A slender body moves through still air at a Mach number of 2.0, generating the Mach wave shown. The Mach angle μ (given by $\sin\mu = 1/M$) is: **[1 mark]**



(A) $45°$

(B) $60°$

(C) $30°$

(D) $19.5°$

Q8. A normal shock stands in a stream of air ($\gamma = 1.4$) at an upstream Mach number of 2.0. The static pressure ratio p_2/p_1 across the shock $\left(p_2/p_1 = 1 + \frac{2\gamma}{\gamma+1}(M_1^2 - 1)\right)$ is: **[1 mark]**

(A) 4.0

(B) 4.5

(C) 5.0

(D) 1.5

Q9. For the same normal shock in air ($\gamma = 1.4$) at an upstream Mach number of 2.0, the static temperature ratio T_2/T_1 across the shock is nearest to: **[1 mark]**

(A) 1.50

(B) 4.50

(C) 2.67

(D) 1.69

Q10. A laminar boundary layer grows over a flat plate. At a station where the local Reynolds number is 10^6, the local skin-friction coefficient given by the Blasius result $\left(c_f = 0.664/\sqrt{Re_x}\right)$ is: **[1 mark]**

(A) 1.328×10^{-3}

(B) 5.00×10^{-3}

(C) 6.64×10^{-3}

(D) 6.64×10^{-4}

Q11. At a test condition the air has a dynamic viscosity of 1.8×10^{-5} Pa · s and a density of 1.2 kg/m^3. The kinematic viscosity of the air is: **[1 mark]**

(A) 1.5×10^{-5} m^2/s

(B) 2.16×10^{-5} m^2/s

(C) 6.67×10^{4} m^2/s

(D) 1.5×10^{-6} m^2/s

Q12. For a thin symmetric airfoil the section lift-curve slope is 2π per radian. Expressed per degree of angle of attack, the lift-curve slope is nearest to: **[1 mark]**

(A) 0.0175 deg^{-1}

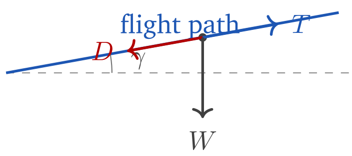
(B) 0.110 deg^{-1}

(C) 6.28 deg^{-1}

(D) 0.628 deg^{-1}

Flight Mechanics & Space Dynamics

Q13. An aircraft of weight 20,000 N climbs steadily in a straight line. The engine thrust is 6,000 N and the total drag is 4,000 N, as shown in the free-body diagram. Using $\sin\gamma = (T - D)/W$, the climb angle γ above the horizontal is nearest to: **[1 mark]**



(A) $5.74°$

(B) $11.5°$

(C) $2.87°$

(D) $30.0°$

Q14. An aircraft flies a steady, coordinated level turn at a true airspeed of 100 m/s with a bank angle of $45°$. Using $R = V^2/(g\tan\phi)$, the radius of the turn is nearest to: **[1 mark]**

(A) 509 m

(B) 2039 m

(C) 1019 m

(D) 100 m

Q15. An aircraft of weight 20,000 N has an excess power (power available minus power required) of 200 kW at a given speed. The maximum steady rate of climb $\big(\text{R/C} = (P_a - P_r)/W\big)$ is: **[1 mark]**

(A) 2 m/s

(B) 40 m/s

(C) 5 m/s

(D) 10 m/s

Q16. An aircraft has a 1-g stall speed of 50 m/s in level flight. In a steady, coordinated turn it pulls a load factor of 2. The stall speed in this turn $\left(V = V_s\sqrt{n}\right)$ is nearest to: **[1 mark]**

(A) 70.7 m/s

(B) 50.0 m/s

(C) 100.0 m/s

(D) 35.4 m/s

Q17. A horizontal-tail surface has a planform area of 4 m^2 and its aerodynamic centre lies 6 m aft of the aircraft centre of gravity. The wing area is 24 m^2 and the mean aerodynamic chord is 2 m. The horizontal-tail volume ratio $\left(V_H = l_t S_t/(\bar{c}\,S)\right)$ is: **[1 mark]**

(A) 0.25

(B) 1.00

(C) 0.50

(D) 2.00

Q18. For an airplane to possess directional (weathercock) static stability about its vertical axis, the yawing-moment coefficient C_n must vary with the sideslip angle β such that: **[1 mark]**

(A) $\dfrac{dC_n}{d\beta} > 0$

(B) $\dfrac{dC_n}{d\beta} < 0$

(C) $\dfrac{dC_n}{d\beta} = 0$

(D) $\dfrac{dC_l}{d\beta} > 0$

Q19. An aircraft flying straight and level at 100 m/s performs a symmetric pull-up on a circular arc of radius 1000 m in the vertical plane. Using $n = 1 + V^2/(gR)$, the load factor at the bottom of the pull-up is nearest to: **[1 mark]**

(A) 2.02

(B) 1.02

(C) 3.04

(D) 1.00

Q20. A satellite moves in a circular orbit of radius 7000 km about the Earth ($\mu = 3.986 \times 10^{14}$ m^3/s^2). Using $T = 2\pi\sqrt{a^3/\mu}$, the orbital period is nearest to: **[1 mark]**

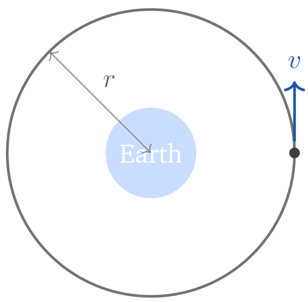
(A) 84.5 min

(B) 97.2 min

(C) 60.0 min

(D) 120.0 min

Q21. A satellite is in a circular orbit of radius 8000 km about the Earth ($\mu = 3.986 \times 10^{14}$ m^3/s^2), as shown. Using $\varepsilon = -\mu/(2a)$, the specific orbital (mechanical) energy per unit mass is nearest to: **[2 marks]**



(A) -24.9 MJ/kg

(B) -49.8 MJ/kg

(C) -12.5 MJ/kg

(D) -3.99 MJ/kg

Q22. A satellite is in an elliptic orbit about the Earth ($\mu = 3.986 \times 10^{14}$ m^3/s^2) with a semi-major axis of $10{,}000$ km. Using the vis-viva equation $v = \sqrt{\mu(2/r - 1/a)}$, its speed at the point where $r = 7000$ km is nearest to: **[2 marks]**

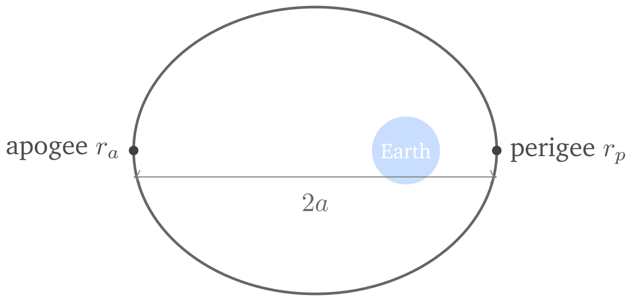
(A) 7.55 km/s

(B) 6.31 km/s

(C) 9.35 km/s

(D) 8.60 km/s

Q23. A satellite orbits the Earth with a perigee radius of 7000 km and an apogee radius of 9000 km, as shown. The eccentricity of the orbit $\left(e = (r_a - r_p)/(r_a + r_p)\right)$ is: **[2 marks]**



(A) 0.250

(B) 0.200

(C) 0.100

(D) 0.125

Aerospace Structures

Q24. A straight prismatic bar of length 2 m and cross-sectional area 500 mm^2 is made of a material with Young's modulus 200 GPa and carries an axial tensile load of 100 kN. The elongation of the bar $\left(\delta = PL/AE\right)$ is: **[2 marks]**

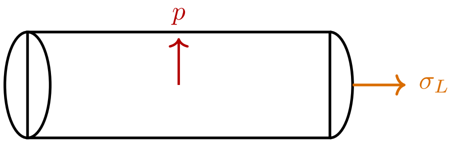
(A) 1.0 mm

(B) 4.0 mm

(C) 2.0 mm

(D) 0.5 mm

Q25. A thin-walled cylindrical pressure vessel of internal diameter 1 m and wall thickness 10 mm carries an internal gauge pressure of 2 MPa, as shown. The longitudinal (axial) stress in the wall $\left(\sigma_L = pd/4t\right)$ is: **[2 marks]**



$d = 1$ m, $t = 10$ mm

(A) 100 MPa

(B) 50 MPa

(C) 200 MPa

(D) 25 MPa

Q26. A straight bar is rigidly held between two fixed supports so that it cannot expand. Its material has a Young's modulus of 200 GPa and a coefficient of thermal expansion of 12×10^{-6} /K. The bar is heated uniformly through 50 K. The thermal (compressive) stress induced $\left(\sigma = E\alpha\,\Delta T\right)$ is: **[2 marks]**

(A) 60 MPa

(B) 120 MPa

(C) 240 MPa

(D) 30 MPa

Q27. A solid circular shaft of diameter 40 mm and length 1 m is made of a material with shear modulus 80 GPa and transmits a torque of 500 N·m. Using $\theta = TL/(GJ)$ with $J = \pi d^4/32$, the angle of twist over the length of the shaft is nearest to: **[2 marks]**

(A) 2.85°

(B) 0.71°

(C) $5.70°$

(D) $1.42°$

Q28. A straight column of length 2 m is fixed at its base and free at its top (fixed–free end conditions), as shown. It has a second moment of area of 1×10^6 mm^4 and is made of a material with Young's modulus 200 GPa. The Euler critical buckling load $\left(P_{cr} = \pi^2 EI/(4L^2)\right)$ is nearest to: **[2 marks]**

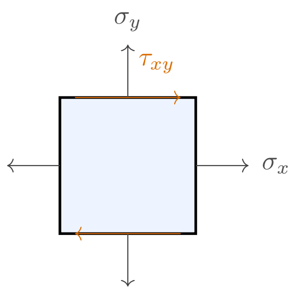
(A) 123 kN

(B) 493 kN

(C) 246 kN

(D) 62 kN

Q29. At a point in a loaded member the plane-stress components are $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa and $\tau_{xy} = 40$ MPa, as shown on the stress element. The minor (minimum) principal stress at the point is: **[2 marks]**



(A) 120 MPa

(B) 70 MPa

(C) 20 MPa

(D) 50 MPa

Q30. At the same point the plane-stress state has principal stresses of 120 MPa and 20 MPa (both in-plane, with zero out-of-plane stress). The von Mises equivalent stress $\left(\sigma_{vm} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}\right)$ is nearest to: **[2 marks]**

(A) 100 MPa

(B) 140 MPa

(C) 50 MPa

(D) 111 MPa

Q31. A single-degree-of-freedom system has a mass of 2 kg, a spring stiffness of 8000 N/m and a viscous damper with a damping coefficient of 40 N · s/m. The damping ratio of the system $\left(\zeta = c/(2\sqrt{km})\right)$ is nearest to: **[2 marks]**

(A) 0.316

(B) 0.080

(C) 0.158

(D) 0.500

Q32. A thin-walled closed section encloses a mean area of 0.01 m^2 and carries a torque of 500 N·m. Using the Bredt–Batho theory, the shear flow in the wall $\left(q = T/(2A_m)\right)$ is: **[2 marks]**

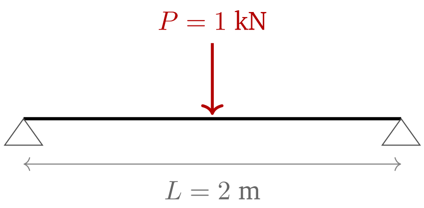
(A) 25 kN/m

(B) 12.5 kN/m

(C) 50 kN/m

(D) 6.25 kN/m

Q33. A simply supported beam of span 2 m carries a concentrated load of 1 kN at mid-span, as shown. The beam has $E = 200$ GPa and $I = 1 \times 10^6$ mm^4. The mid-span deflection $\left(\delta = PL^3/48EI\right)$ is nearest to: **[2 marks]**



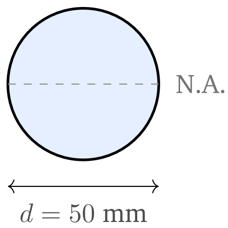
(A) 3.33 mm

(B) 1.67 mm

(C) 0.833 mm

(D) 5.00 mm

Q34. A beam has the solid circular cross-section of diameter 50 mm shown. At a section the bending moment is 2 kN·m. The maximum bending (flexural) stress $\left(\sigma = 32M/\pi d^3\right)$ is nearest to: **[2 marks]**



(A) 81.5 MPa

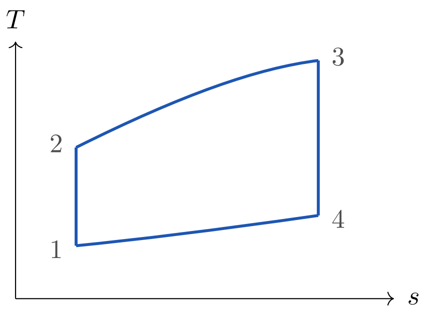
(B) 163 MPa

(C) 326 MPa

(D) 40.7 MPa

Propulsion

Q35. An ideal air-standard Brayton cycle operates with a compressor pressure ratio of 10 and $\gamma = 1.4$, as shown on the T–s diagram. The thermal efficiency $\left(\eta = 1 - r_p^{-(\gamma-1)/\gamma}\right)$ is nearest to: **[2 marks]**



(A) 30.0%

(B) 60.0%

(C) 37.5%

(D) 48.2%

Q36. A turbojet flies at a speed of 250 m/s and produces an exhaust jet of velocity 600 m/s. Neglecting the fuel mass flow and pressure-thrust terms, the specific thrust (thrust per unit air mass flow rate) is: **[2 marks]**

(A) 850 N · s/kg

(B) 350 N · s/kg

(C) 600 N · s/kg

(D) 250 N · s/kg

Q37. In the combustor of a gas-turbine engine air enters at a stagnation temperature of 600 K and leaves at a stagnation temperature of 1200 K. Taking $c_p = 1005$ J/kg · K and neglecting the fuel mass flow, the heat added per unit mass of air $\left(q = c_p\,\Delta T_0\right)$ is nearest to: **[2 marks]**

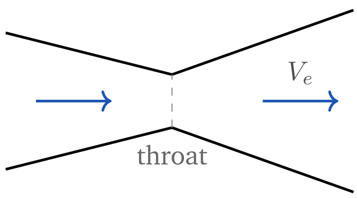
(A) 1206 kJ/kg

(B) 402 kJ/kg

(C) 603 kJ/kg

(D) 300 kJ/kg

Q38. Air expands through the convergent–divergent nozzle shown from a chamber to the exit, with a static-temperature drop of 400 K and negligible inlet velocity. Taking $c_p = 1005$ J/kg · K, the exit velocity $\left(V_e = \sqrt{2c_p\,\Delta T}\right)$ is nearest to: **[2 marks]**



(A) 449 m/s

(B) 897 m/s

(C) 634 m/s

(D) 1268 m/s

Q39. Air ($\gamma = 1.4$) is accelerated through a nozzle until it is just choked at the throat ($M = 1$). The ratio of the static temperature at the throat to the stagnation temperature, $T^*/T_0 = 2/(\gamma + 1)$, is: **[2 marks]**

(A) 0.528

(B) 0.634

(C) 0.500

(D) 0.833

Q40. In an axial-flow compressor stage the mean blade speed is 200 m/s and the whirl (tangential) component of the absolute velocity rises by 180 m/s across the rotor. Taking $c_p = 1005$ J/kg·K, the stagnation-temperature rise of the air across the stage $\left(\Delta T_0 = U\,\Delta C_w/c_p\right)$ is nearest to: **[2 marks]**

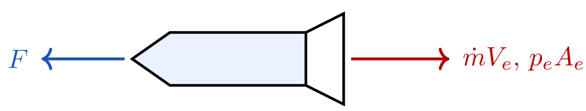
(A) 18.0 K

(B) 35.8 K

(C) 72.0 K

(D) 50.0 K

Q41. A rocket engine expels propellant at a mass flow rate of 50 kg/s with an exhaust velocity of 2500 m/s. The nozzle exit area is 0.2 m^2, the exit static pressure is 100 kPa and the ambient pressure is 50 kPa, as shown. The total thrust $\left(F = \dot{m}V_e + (p_e - p_a)A_e\right)$ is: **[2 marks]**



(A) 135 kN

(B) 125 kN

(C) 115 kN

(D) 145 kN

Q42. A rocket engine produces a thrust of 9810 N while consuming propellant at a mass flow rate of 5 kg/s. Taking $g_0 = 9.81$ m/s^2, the specific impulse $\left(I_{sp} = F/(\dot{m}g_0)\right)$ is: **[2 marks]**

(A) 200 s

(B) 100 s

(C) 300 s

(D) 250 s

Q43. A single-stage rocket has a specific impulse of 250 s (with $g_0 = 9.81$ m/s^2) and an initial-to-final mass ratio of 2. Using the Tsiolkovsky rocket equation $\left(\Delta v = I_{sp}\, g_0 \ln(m_0/m_f)\right)$, the ideal velocity increment is nearest to: **[2 marks]**

(A) 2453 m/s

(B) 1700 m/s

(C) 3400 m/s

(D) 850 m/s

Q44. A gas-turbine combustor burns a hydrocarbon fuel whose stoichiometric air–fuel ratio is 15. The mixture is run lean at an equivalence ratio of 0.60. The actual air–fuel ratio supplied $\left((A/F)_{\text{actual}} = (A/F)_{\text{stoich}}/\phi\right)$ is: **[2 marks]**

(A) 9

(B) 15

(C) 20

(D) 25

Q45. A jet engine has a propulsive (Froude) efficiency of 0.50 and a thermal efficiency of 0.50. The overall efficiency of the engine $\left(\eta_o = \eta_p\, \eta_{th}\right)$ is: **[2 marks]**

(A) 1.00

(B) 0.75

(C) 0.25

(D) 0.50

Q46. The turbine of a gas-turbine engine receives gas at a stagnation temperature of 1200 K and expands it isentropically through an expansion (pressure) ratio of 8 ($\gamma = 1.4$). The turbine-exit stagnation temperature $\left(T_{04} = T_{03}\, r_p^{-(\gamma-1)/\gamma}\right)$ is nearest to: **[2 marks]**

(A) 663 K

(B) 480 K

(C) 800 K

(D) 1200 K

Detailed Solutions

Q1.

Solution

Concept – Mach number: The Mach number is the ratio of flight speed to the local speed of sound, $M = V/a$, where $a = \sqrt{\gamma RT}$.

Step 1 – list the data: $V = 170$ m/s, $T = 288$ K, $\gamma = 1.4$, $R = 287$ J/kg · K.

Step 2 – form the product γR**:** $\gamma R = 1.4 \times 287 = 401.8$

Step 3 – multiply by the temperature: $\gamma RT = 401.8 \times 288 = 115718.4$

Step 4 – take the square root for the speed of sound: $a = \sqrt{115718.4} = 340.17$ m/s

Step 5 – divide the flight speed by the speed of sound: $M = \dfrac{170}{340.17}$

Step 6 – evaluate: $M = 0.4998 \approx 0.50$

Final Answer: $M \approx 0.50 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – Prandtl–Glauert compressibility correction: For subsonic compressible flow the pressure coefficient is scaled from its incompressible value by $C_p = \dfrac{C_{p,0}}{\sqrt{1 - M_\infty^2}}$.

Step 1 – list the data: $C_{p,0} = 0.40$, $M_\infty = 0.60$.

Step 2 – square the Mach number: $M_\infty^2 = 0.60^2 = 0.36$

Step 3 – form the term under the root: $1 - M_\infty^2 = 1 - 0.36 = 0.64$

Step 4 – take the square root: $\sqrt{0.64} = 0.80$

Step 5 – divide the incompressible value by that root: $C_p = \dfrac{0.40}{0.80}$

Step 6 – evaluate: $C_p = 0.50$

Final Answer: $C_p = 0.50 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – drag force from the drag coefficient: $D = C_D\, q\, A$ with the dynamic pressure $q = \frac{1}{2}\rho V^2$.

Step 1 – list the data: $C_D = 0.40$, $A = 0.5\ \text{m}^2$, $\rho = 1.225\ \text{kg/m}^3$, $V = 40\ \text{m/s}$.

Step 2 – square the velocity: $V^2 = 40^2 = 1600$

Step 3 – compute the dynamic pressure: $q = \frac{1}{2}(1.225)(1600)$

$q = 0.6125 \times 1600 = 980\ \text{Pa}$

Step 4 – multiply by the area: $q\, A = 980 \times 0.5 = 490\ \text{N}$

Step 5 – multiply by the drag coefficient: $D = 0.40 \times 490$

Step 6 – evaluate: $D = 196\ \text{N}$

Final Answer: $D = 196\ \text{N} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept – lift force: $L = C_L\, q\, S$ with $q = \frac{1}{2}\rho V^2$.

Step 1 – list the data: $C_L = 0.40$, $\rho = 1.225\ \text{kg/m}^3$, $V = 50\ \text{m/s}$, $S = 20\ \text{m}^2$.

Step 2 – square the velocity: $V^2 = 50^2 = 2500$

Step 3 – compute the dynamic pressure: $q = \frac{1}{2}(1.225)(2500)$

$q = 0.6125 \times 2500 = 1531.25\ \text{Pa}$

Step 4 – multiply by the wing area: $q\, S = 1531.25 \times 20 = 30625\ \text{N}$

Step 5 – multiply by the lift coefficient: $L = 0.40 \times 30625$

Step 6 – evaluate: $L = 12250\ \text{N}$

Final Answer: $L = 12250\ \text{N} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – drag polar of a finite-wing aircraft: $C_D = C_{D,0} + \dfrac{C_L^2}{\pi e\, AR}$, the sum of parasite drag and induced drag.

Step 1 – list the data: $C_{D,0} = 0.020$, $C_L = 0.60$, $e = 0.85$, $AR = 7$.

Step 2 – square the lift coefficient: $C_L^2 = 0.60^2 = 0.36$

Step 3 – form the induced-drag denominator: $\pi e\, AR = 3.1416 \times 0.85 \times 7$

$= 3.1416 \times 5.95 = 18.692$

Step 4 – compute the induced-drag coefficient: $C_{D,i} = \dfrac{0.36}{18.692} = 0.01926$

Step 5 – add the parasite drag: $C_D = 0.020 + 0.01926$

Step 6 – evaluate: $C_D = 0.03926 \approx 0.0393$

Final Answer: $C_D \approx 0.0393 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – wing loading: Wing loading is the aircraft weight divided by the wing planform area, W/S.

Step 1 – list the data: $W = 30000$ N, $S = 20$ m^2.

Step 2 – write the definition: $\dfrac{W}{S} = \dfrac{30000}{20}$

Step 3 – evaluate: $\dfrac{W}{S} = 1500\ \text{N/m}^2$

Final Answer: $W/S = 1500\ \text{N/m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q6

Q7.

Solution

Concept – Mach angle: A weak (Mach) wave in supersonic flow makes an angle μ with the flow direction such that $\sin\mu = 1/M$.

Step 1 – list the data: $M = 2.0$.

Step 2 – form the sine of the Mach angle: $\sin\mu = \dfrac{1}{2.0} = 0.5$

Step 3 – take the inverse sine: $\mu = \sin^{-1}(0.5)$

Step 4 – evaluate: $\mu = 30^\circ$

Final Answer: $\mu = 30^\circ \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – static pressure ratio across a normal shock: $\frac{p_2}{p_1} = 1 + \frac{2\gamma}{\gamma+1}\left(M_1^2 - 1\right)$.

Step 1 – list the data: $\gamma = 1.4$, $M_1 = 2.0$.

Step 2 – square the upstream Mach number: $M_1^2 = 2.0^2 = 4$

Step 3 – form the coefficient $\frac{2\gamma}{\gamma+1}$**:** $\frac{2 \times 1.4}{1.4+1} = \frac{2.8}{2.4} = 1.1667$

Step 4 – form the bracket $M_1^2 - 1$**:** $4 - 1 = 3$

Step 5 – multiply and add 1**:** $\frac{p_2}{p_1} = 1 + 1.1667 \times 3 = 1 + 3.5$

Step 6 – evaluate: $\frac{p_2}{p_1} = 4.5$

Final Answer: $p_2/p_1 = 4.5 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – static temperature ratio across a normal shock: $\frac{T_2}{T_1} = \frac{\left[2\gamma M_1^2 - (\gamma-1)\right]\left[(\gamma-1)M_1^2 + 2\right]}{(\gamma+1)^2 M_1^2}$.

Step 1 – list the data: $\gamma = 1.4$, $M_1 = 2.0$, so $M_1^2 = 4$.

Step 2 – evaluate the first bracket $2\gamma M_1^2 - (\gamma - 1)$**:** $2 \times 1.4 \times 4 = 11.2$

$11.2 - 0.4 = 10.8$

Step 3 – evaluate the second bracket $(\gamma-1)M_1^2 + 2$**:** $0.4 \times 4 = 1.6$

$1.6 + 2 = 3.6$

Step 4 – multiply the two brackets: $10.8 \times 3.6 = 38.88$

Step 5 – evaluate the denominator $(\gamma+1)^2 M_1^2$**:** $(2.4)^2 = 5.76$

$5.76 \times 4 = 23.04$

Step 6 – divide: $\frac{T_2}{T_1} = \frac{38.88}{23.04} = 1.6875 \approx 1.69$

Final Answer: $T_2/T_1 \approx 1.69 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – Blasius local skin-friction coefficient: $c_f = \dfrac{0.664}{\sqrt{Re_x}}$.

Step 1 – list the data: $Re_x = 10^6$.

Step 2 – take the square root of the Reynolds number: $\sqrt{Re_x} = \sqrt{10^6} = 1000$

Step 3 – substitute into the formula: $c_f = \dfrac{0.664}{1000}$

Step 4 – evaluate: $c_f = 6.64 \times 10^{-4}$

Final Answer: $c_f = 6.64 \times 10^{-4} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – kinematic viscosity: The kinematic viscosity is the dynamic viscosity divided by the density, $\nu = \mu/\rho$.

Step 1 – list the data: $\mu = 1.8 \times 10^{-5}$ Pa · s, $\rho = 1.2$ kg/m^3.

Step 2 – write the definition: $\nu = \dfrac{1.8 \times 10^{-5}}{1.2}$

Step 3 – divide the mantissas: $\dfrac{1.8}{1.2} = 1.5$

Step 4 – attach the power of ten: $\nu = 1.5 \times 10^{-5}\ \text{m}^2/\text{s}$

Final Answer: $\nu = 1.5 \times 10^{-5}\ \text{m}^2/\text{s} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – lift-curve slope of a thin airfoil: The thin-airfoil result gives a slope of 2π per radian; to convert to a per-degree value, multiply by $\pi/180$.

Step 1 – list the data: slope $= 2\pi$ per radian.

Step 2 – evaluate 2π: $2\pi = 6.2832$ per radian

Step 3 – form the radian-to-degree factor: $\frac{\pi}{180} = 0.017453$ rad/deg

Step 4 – multiply the slope by the factor: 6.2832×0.017453

Step 5 – evaluate: $= 0.1097 \approx 0.110\ \text{deg}^{-1}$

Step 6 – note the trap: Option (C) $6.28\ \text{deg}^{-1}$ is the per-radian value used without conversion, which is wrong here.

Final Answer: slope $\approx 0.110\ \text{deg}^{-1} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept – climb angle in a steady climb: Resolving forces along the flight path, $T = D + W \sin\gamma$, so $\sin\gamma = \frac{T - D}{W}$.

Step 1 – list the data: $T = 6000$ N, $D = 4000$ N, $W = 20000$ N.

Step 2 – form the excess thrust: $T - D = 6000 - 4000 = 2000$ N

Step 3 – divide by the weight: $\sin\gamma = \frac{2000}{20000} = 0.10$

Step 4 – take the inverse sine: $\gamma = \sin^{-1}(0.10)$

Step 5 – evaluate: $\gamma = 5.74°$

Final Answer: $\gamma \approx 5.74° \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – radius of a level, coordinated turn: Balancing the horizontal component of lift against centripetal force gives $R = \frac{V^2}{g \tan\phi}$.

Step 1 – list the data: $V = 100$ m/s, $\phi = 45°$, $g = 9.81$ m/s^2.

Step 2 – square the velocity: $V^2 = 100^2 = 10000$

Step 3 – evaluate $\tan\phi$: $\tan 45° = 1$

Step 4 – form the denominator $g \tan\phi$: $9.81 \times 1 = 9.81$

Step 5 – divide: $R = \frac{10000}{9.81}$

Step 6 – evaluate: $R = 1019.4$ m ≈ 1019 m

Final Answer: $R \approx 1019$ m $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept – rate of climb from excess power: The steady rate of climb equals the excess power divided by the weight, $\mathrm{R/C} = \dfrac{P_a - P_r}{W}$.

Step 1 – list the data: $P_a - P_r = 200\ \mathrm{kW} = 200000\ \mathrm{W}$, $W = 20000\ \mathrm{N}$.

Step 2 – substitute into the formula: $\mathrm{R/C} = \dfrac{200000}{20000}$

Step 3 – evaluate: $\mathrm{R/C} = 10\ \mathrm{m/s}$

Final Answer: $\mathrm{R/C} = 10\ \mathrm{m/s} \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – stall speed in a maneuver: The stall speed grows with the square root of the load factor, $V = V_s\sqrt{n}$, because the required lift rises by the factor n.

Step 1 – list the data: $V_s = 50\ \mathrm{m/s}$, $n = 2$.

Step 2 – take the square root of the load factor: $\sqrt{n} = \sqrt{2} = 1.4142$

Step 3 – multiply by the level stall speed: $V = 50 \times 1.4142$

Step 4 – evaluate: $V = 70.71\ \mathrm{m/s} \approx 70.7\ \mathrm{m/s}$

Final Answer: $V \approx 70.7\ \mathrm{m/s} \Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – horizontal-tail volume ratio: $V_H = \dfrac{l_t\,S_t}{\bar{c}\,S}$, a non-dimensional measure of tail effectiveness.

Step 1 – list the data: $l_t = 6\ \mathrm{m}$, $S_t = 4\ \mathrm{m}^2$, $\bar{c} = 2\ \mathrm{m}$, $S = 24\ \mathrm{m}^2$.

Step 2 – form the numerator l_tS_t: $6 \times 4 = 24$

Step 3 – form the denominator $\bar{c}\,S$: $2 \times 24 = 48$

Step 4 – divide: $V_H = \dfrac{24}{48}$

Step 5 – evaluate: $V_H = 0.50$

Final Answer: $V_H = 0.50 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q17

Q18.

Solution

Concept – directional (weathercock) static stability: A directionally stable aircraft develops a restoring yawing moment when disturbed in sideslip. With the sign convention that a positive sideslip β (nose left of the relative wind) should produce a positive (nose-right, restoring) yawing moment, stability requires $\dfrac{dC_n}{d\beta} > 0$.

Step 1 – consider a positive sideslip disturbance: The relative wind strikes the fuselage and fin from the side, generating a side force on the vertical tail.

Step 2 – identify the restoring moment: This side force acts behind the centre of gravity and yaws the nose back into the wind, reducing β.

Step 3 – state the condition: For that moment to be restoring, C_n must increase with β, i.e. $\dfrac{dC_n}{d\beta} > 0$.

Step 4 – eliminate the distractors: $\dfrac{dC_n}{d\beta} < 0$ is unstable; $= 0$ is neutral; $\dfrac{dC_l}{d\beta}$ concerns roll (lateral) stability, not directional.

Final Answer: $\dfrac{dC_n}{d\beta} > 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q18

Q19.

Solution

Concept – load factor in a pull-up: At the bottom of a circular pull-up the lift must support the weight and provide the centripetal force, so $n = 1 + \dfrac{V^2}{gR}$.

Step 1 – list the data: $V = 100$ m/s, $R = 1000$ m, $g = 9.81$ m/s^2.

Step 2 – square the velocity: $V^2 = 100^2 = 10000$

Step 3 – form the denominator gR**:** $9.81 \times 1000 = 9810$

Step 4 – form the centripetal term: $\dfrac{V^2}{gR} = \dfrac{10000}{9810} = 1.019$

Step 5 – add 1**:** $n = 1 + 1.019 = 2.019$

Step 6 – round: $n \approx 2.02$

Final Answer: $n \approx 2.02 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – period of a circular orbit: $T = 2\pi\sqrt{\dfrac{a^3}{\mu}}$, with a the orbit radius for a circular orbit.

Step 1 – list the data: $a = 7000$ km $= 7 \times 10^6$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – cube the radius: $a^3 = (7 \times 10^6)^3 = 3.43 \times 10^{20}$ m^3

Step 3 – divide by μ: $\dfrac{a^3}{\mu} = \dfrac{3.43 \times 10^{20}}{3.986 \times 10^{14}} = 8.606 \times 10^5$

Step 4 – take the square root: $\sqrt{8.606 \times 10^5} = 927.7$ s

Step 5 – multiply by 2π: $T = 2\pi \times 927.7 = 5829$ s

Step 6 – convert to minutes: $T = \dfrac{5829}{60} = 97.2$ min

Final Answer: $T \approx 97.2$ min $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q20

Q21.

Solution

Concept – specific orbital energy: The mechanical energy per unit mass of an orbit is $\varepsilon = -\dfrac{\mu}{2a}$.

Step 1 – list the data: $a = 8000$ km $= 8 \times 10^6$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – form the denominator $2a$: $2a = 2 \times 8 \times 10^6 = 1.6 \times 10^7$ m

Step 3 – divide μ by $2a$: $\dfrac{\mu}{2a} = \dfrac{3.986 \times 10^{14}}{1.6 \times 10^7}$

Step 4 – evaluate: $= 2.491 \times 10^7$ J/kg

Step 5 – attach the sign: $\varepsilon = -2.491 \times 10^7$ J/kg $= -24.9$ MJ/kg

Final Answer: $\varepsilon \approx -24.9$ MJ/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – vis-viva equation: The speed at a point of an orbit is $v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$.

Step 1 – list the data: $\mu = 3.986 \times 10^{14}\ \mathrm{m^3/s^2}$, $r = 7 \times 10^6$ m, $a = 1 \times 10^7$ m.

Step 2 – form $\frac{2}{r}$: $\frac{2}{7 \times 10^6} = 2.857 \times 10^{-7}$

Step 3 – form $\frac{1}{a}$: $\frac{1}{1 \times 10^7} = 1.000 \times 10^{-7}$

Step 4 – subtract: $2.857 \times 10^{-7} - 1.000 \times 10^{-7} = 1.857 \times 10^{-7}$

Step 5 – multiply by μ: $3.986 \times 10^{14} \times 1.857 \times 10^{-7} = 7.403 \times 10^7$

Step 6 – take the square root: $v = \sqrt{7.403 \times 10^7} = 8604\ \mathrm{m/s} \approx 8.60\ \mathrm{km/s}$

Final Answer: $v \approx 8.60\ \mathrm{km/s} \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q22

Q23.

Solution

Concept – eccentricity from apsidal radii: $e = \frac{r_a - r_p}{r_a + r_p}$, where r_a and r_p are the apogee and perigee radii.

Step 1 – list the data: $r_p = 7000$ km, $r_a = 9000$ km.

Step 2 – form the numerator: $r_a - r_p = 9000 - 7000 = 2000$ km

Step 3 – form the denominator: $r_a + r_p = 9000 + 7000 = 16000$ km

Step 4 – divide: $e = \frac{2000}{16000}$

Step 5 – evaluate: $e = 0.125$

Final Answer: $e = 0.125 \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – axial elongation of a bar: $\delta = \frac{PL}{AE}$.

Step 1 – list the data: $P = 100$ kN $= 100000$ N, $L = 2$ m, $A = 500\ \mathrm{mm^2} = 500 \times 10^{-6}\ \mathrm{m^2}$, $E = 200$ GPa $= 200 \times 10^9$ Pa.

Step 2 – form the numerator PL: $PL = 100000 \times 2 = 200000$

Step 3 – form the denominator AE: $AE = 500 \times 10^{-6} \times 200 \times 10^9$
$= 1 \times 10^8$

Step 4 – divide: $\delta = \dfrac{200000}{1 \times 10^8}$

Step 5 – evaluate: $\delta = 2 \times 10^{-3}$ m $= 2.0$ mm

Final Answer: $\delta = 2.0$ mm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – longitudinal stress in a thin cylinder: The axial (longitudinal) stress is $\sigma_L = \dfrac{pd}{4t}$, exactly half the hoop stress.

Step 1 – list the data: $p = 2$ MPa $= 2 \times 10^6$ Pa, $d = 1$ m, $t = 10$ mm $= 0.01$ m.

Step 2 – form the numerator pd: $pd = 2 \times 10^6 \times 1 = 2 \times 10^6$

Step 3 – form the denominator $4t$: $4t = 4 \times 0.01 = 0.04$

Step 4 – divide: $\sigma_L = \dfrac{2 \times 10^6}{0.04}$

Step 5 – evaluate: $\sigma_L = 5 \times 10^7$ Pa $= 50$ MPa

Final Answer: $\sigma_L = 50$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q25

Q26.

Solution

Concept – thermal stress in a fully restrained bar: When free expansion $\alpha\Delta T$ is completely prevented, the induced stress is $\sigma = E\alpha\,\Delta T$.

Step 1 – list the data: $E = 200$ GPa $= 200 \times 10^9$ Pa, $\alpha = 12 \times 10^{-6}$ /K, $\Delta T = 50$ K.

Step 2 – form the product $\alpha\,\Delta T$: $\alpha\,\Delta T = 12 \times 10^{-6} \times 50 = 6 \times 10^{-4}$

Step 3 – multiply by E: $\sigma = 200 \times 10^9 \times 6 \times 10^{-4}$

Step 4 – evaluate: $\sigma = 1.2 \times 10^8$ Pa $= 120$ MPa

Final Answer: $\sigma = 120$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – angle of twist of a shaft: $\theta = \dfrac{TL}{GJ}$ with the polar second moment of area $J = \dfrac{\pi d^4}{32}$.

Step 1 – list the data: $T = 500$ N·m, $L = 1$ m, $G = 80$ GPa $= 80 \times 10^9$ Pa, $d = 40$ mm $= 0.04$ m.

Step 2 – raise the diameter to the fourth power: $d^4 = (0.04)^4 = 2.56 \times 10^{-6}$ m^4

Step 3 – compute the polar moment J: $J = \dfrac{\pi \times 2.56 \times 10^{-6}}{32}$

$J = \dfrac{8.0425 \times 10^{-6}}{32} = 2.513 \times 10^{-7}$ m^4

Step 4 – form the product GJ: $GJ = 80 \times 10^9 \times 2.513 \times 10^{-7} = 20106$

Step 5 – divide TL by GJ: $\theta = \dfrac{500 \times 1}{20106} = 0.02487$ rad

Step 6 – convert to degrees: $\theta = 0.02487 \times \dfrac{180}{\pi} = 1.425^\circ \approx 1.42^\circ$

Final Answer: $\theta \approx 1.42^\circ \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q27

Q28.

Solution

Concept – Euler buckling of a fixed–free column: For a column fixed at one end and free at the other, the effective length is $2L$, giving $P_{cr} = \dfrac{\pi^2 EI}{(2L)^2} = \dfrac{\pi^2 EI}{4L^2}$.

Step 1 – list the data: $E = 200$ GPa $= 200 \times 10^9$ Pa, $I = 1 \times 10^6$ mm^4 $= 1 \times 10^{-6}$ m^4, $L = 2$ m.

Step 2 – form the numerator $\pi^2 EI$: $\pi^2 = 9.8696$

$\pi^2 EI = 9.8696 \times 200 \times 10^9 \times 1 \times 10^{-6}$

$= 9.8696 \times 2 \times 10^5 = 1.97392 \times 10^6$

Step 3 – form the denominator $4L^2$: $L^2 = 2^2 = 4$

$4L^2 = 4 \times 4 = 16$

Step 4 – divide: $P_{cr} = \dfrac{1.97392 \times 10^6}{16}$

Step 5 – evaluate: $P_{cr} = 123370$ N ≈ 123 kN

Final Answer: $P_{cr} \approx 123$ kN $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

Concept – principal stresses in plane stress: $\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$; the minor principal stress uses the minus sign.

Step 1 – list the data: $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa, $\tau_{xy} = 40$ MPa.

Step 2 – form the average stress: $\frac{\sigma_x + \sigma_y}{2} = \frac{100 + 40}{2} = 70$ MPa

Step 3 – form the half-difference: $\frac{\sigma_x - \sigma_y}{2} = \frac{100 - 40}{2} = 30$ MPa

Step 4 – compute the radius of Mohr's circle: $R = \sqrt{30^2 + 40^2} = \sqrt{900 + 1600}$

$R = \sqrt{2500} = 50$ MPa

Step 5 – subtract the radius from the average: $\sigma_2 = 70 - 50$

Step 6 – evaluate: $\sigma_2 = 20$ MPa

Final Answer: $\sigma_2 = 20 \text{ MPa} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q29

Q30.

Solution

Concept – von Mises stress in plane stress: With in-plane principal stresses σ_1 and σ_2, $\sigma_{vm} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$.

Step 1 – list the data: $\sigma_1 = 120$ MPa, $\sigma_2 = 20$ MPa.

Step 2 – square the major principal stress: $\sigma_1^2 = 120^2 = 14400$

Step 3 – form the cross term $\sigma_1\sigma_2$: $\sigma_1\sigma_2 = 120 \times 20 = 2400$

Step 4 – square the minor principal stress: $\sigma_2^2 = 20^2 = 400$

Step 5 – combine under the root: $14400 - 2400 + 400 = 12400$

Step 6 – take the square root: $\sigma_{vm} = \sqrt{12400} = 111.4 \text{ MPa} \approx 111$ MPa

Final Answer: $\sigma_{vm} \approx 111 \text{ MPa} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – damping ratio of a single-degree-of-freedom system: $\zeta = \dfrac{c}{2\sqrt{km}}$, the ratio of actual damping to critical damping.

Step 1 – list the data: $m = 2$ kg, $k = 8000$ N/m, $c = 40$ N · s/m.

Step 2 – form the product km**:** $km = 8000 \times 2 = 16000$

Step 3 – take the square root: $\sqrt{km} = \sqrt{16000} = 126.49$

Step 4 – form the critical damping $2\sqrt{km}$**:** $2 \times 126.49 = 252.98$

Step 5 – divide the damping coefficient by the critical value: $\zeta = \dfrac{40}{252.98}$

Step 6 – evaluate: $\zeta = 0.158$

Final Answer: $\zeta \approx 0.158 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – shear flow in a thin-walled closed section: By the Bredt–Batho theory the shear flow is $q = \dfrac{T}{2A_m}$, where A_m is the mean enclosed area.

Step 1 – list the data: $T = 500$ N·m, $A_m = 0.01$ m^2.

Step 2 – form the denominator $2A_m$**:** $2A_m = 2 \times 0.01 = 0.02$ m^2

Step 3 – divide the torque by $2A_m$**:** $q = \dfrac{500}{0.02}$

Step 4 – evaluate: $q = 25000$ N/m $= 25$ kN/m

Final Answer: $q = 25$ kN/m $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – mid-span deflection of a simply supported beam: For a central point load, $\delta = \dfrac{PL^3}{48EI}$.

Step 1 – list the data: $P = 1$ kN $= 1000$ N, $L = 2$ m, $E = 200$ GPa $= 200 \times 10^9$ Pa, $I = 1 \times 10^6$ mm^4 $= 1 \times 10^{-6}$ m^4.

Step 2 – cube the span: $L^3 = 2^3 = 8$ m^3

Step 3 – form the numerator PL^3: $PL^3 = 1000 \times 8 = 8000$

Step 4 – form the denominator $48EI$: $EI = 200 \times 10^9 \times 1 \times 10^{-6} = 2 \times 10^5$

$48EI = 48 \times 2 \times 10^5 = 9.6 \times 10^6$

Step 5 – divide: $\delta = \dfrac{8000}{9.6 \times 10^6}$

Step 6 – evaluate: $\delta = 8.33 \times 10^{-4}$ m $= 0.833$ mm

Final Answer: $\delta \approx 0.833$ mm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – maximum bending stress of a circular section: For a solid circle of diameter d, $\sigma = \dfrac{M}{Z}$ with $Z = \dfrac{\pi d^3}{32}$, so $\sigma = \dfrac{32M}{\pi d^3}$.

Step 1 – list the data: $M = 2$ kN $\cdot$ m $= 2000$ N·m, $d = 50$ mm $= 0.05$ m.

Step 2 – cube the diameter: $d^3 = (0.05)^3 = 1.25 \times 10^{-4}$ m^3

Step 3 – form the denominator πd^3: $\pi d^3 = 3.1416 \times 1.25 \times 10^{-4} = 3.927 \times 10^{-4}$

Step 4 – form the numerator $32M$: $32M = 32 \times 2000 = 64000$

Step 5 – divide: $\sigma = \dfrac{64000}{3.927 \times 10^{-4}}$

Step 6 – evaluate: $\sigma = 1.630 \times 10^8$ Pa ≈ 163 MPa

Final Answer: $\sigma \approx 163$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept – thermal efficiency of an ideal Brayton cycle: $\eta = 1 - \dfrac{1}{r_p^{(\gamma-1)/\gamma}}$, a function of pressure ratio only.

Step 1 – list the data: $r_p = 10$, $\gamma = 1.4$.

Step 2 – form the exponent $\dfrac{\gamma - 1}{\gamma}$: $\dfrac{0.4}{1.4} = 0.2857$

Step 3 – raise the pressure ratio to that power: $10^{0.2857} = 1.9307$

Step 4 – take the reciprocal: $\dfrac{1}{1.9307} = 0.5179$

Step 5 – subtract from one: $\eta = 1 - 0.5179 = 0.4821$

Step 6 – express as a percentage: $\eta = 48.2\%$

Final Answer: $\eta \approx 48.2\% \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – specific thrust of a turbojet: Neglecting fuel mass flow and pressure thrust, $\frac{F}{\dot{m}} = V_e - V_0$.

Step 1 – list the data: $V_0 = 250$ m/s, $V_e = 600$ m/s.

Step 2 – subtract the flight speed from the jet speed: $V_e - V_0 = 600 - 250$

Step 3 – evaluate: $\frac{F}{\dot{m}} = 350 \text{ N} \cdot \text{s/kg}$

Final Answer: specific thrust $= 350 \text{ N} \cdot \text{s/kg} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – heat added in the combustor: At constant pressure the heat added per unit mass is $q = c_p \, \Delta T_0 = c_p \, (T_{03} - T_{02})$.

Step 1 – list the data: $c_p = 1005$ J/kg · K, $T_{02} = 600$ K, $T_{03} = 1200$ K.

Step 2 – form the temperature rise: $\Delta T_0 = 1200 - 600 = 600$ K

Step 3 – multiply by c_p: $q = 1005 \times 600$

Step 4 – evaluate: $q = 603000$ J/kg $= 603$ kJ/kg

Final Answer: $q = 603$ kJ/kg $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q37

Q38.

Solution

Concept – exit velocity from an energy balance: With negligible inlet velocity, the enthalpy drop converts to kinetic energy, giving $V_e = \sqrt{2c_p \, \Delta T}$.

Step 1 – list the data: $c_p = 1005$ J/kg · K, $\Delta T = 400$ K.

Step 2 – form the product $2c_p \, \Delta T$: $2 \times 1005 \times 400$

Step 3 – multiply step by step: $2 \times 1005 = 2010$

$2010 \times 400 = 804000$

Step 4 – take the square root: $V_e = \sqrt{804000}$

Step 5 – evaluate: $V_e = 896.7 \text{ m/s} \approx 897 \text{ m/s}$

Final Answer: $V_e \approx 897 \text{ m/s} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – critical (choked) temperature ratio: At the throat with $M = 1$ the isentropic relation gives $\dfrac{T^*}{T_0} = \dfrac{2}{\gamma + 1}$.

Step 1 – list the data: $\gamma = 1.4$.

Step 2 – form the denominator $\gamma + 1$**:** $\gamma + 1 = 1.4 + 1 = 2.4$

Step 3 – divide 2 **by that sum:** $\dfrac{T^*}{T_0} = \dfrac{2}{2.4}$

Step 4 – evaluate: $\dfrac{T^*}{T_0} = 0.8333 \approx 0.833$

Final Answer: $T^*/T_0 \approx 0.833 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – stage temperature rise in an axial compressor: The Euler work per unit mass is $w = U\,\Delta C_w$, and the stagnation-temperature rise is $\Delta T_0 = \dfrac{U\,\Delta C_w}{c_p}$.

Step 1 – list the data: $U = 200 \text{ m/s}$, $\Delta C_w = 180 \text{ m/s}$, $c_p = 1005 \text{ J/kg} \cdot \text{K}$.

Step 2 – form the specific work $U\,\Delta C_w$**:** $U\,\Delta C_w = 200 \times 180 = 36000 \text{ J/kg}$

Step 3 – divide by c_p**:** $\Delta T_0 = \dfrac{36000}{1005}$

Step 4 – evaluate: $\Delta T_0 = 35.82 \text{ K} \approx 35.8 \text{ K}$

Final Answer: $\Delta T_0 \approx 35.8 \text{ K} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – total thrust of a rocket: $F = \dot{m}V_e + (p_e - p_a)A_e$, the sum of momentum thrust and pressure thrust.

Step 1 – list the data: $\dot{m} = 50$ kg/s, $V_e = 2500$ m/s, $p_e = 100$ kPa $= 100000$ Pa, $p_a = 50$ kPa $= 50000$ Pa, $A_e = 0.2$ m^2.

Step 2 – compute the momentum thrust: $\dot{m}V_e = 50 \times 2500 = 125000$ N

Step 3 – form the pressure difference: $p_e - p_a = 100000 - 50000 = 50000$ Pa

Step 4 – compute the pressure thrust: $(p_e - p_a)A_e = 50000 \times 0.2 = 10000$ N

Step 5 – add the two contributions: $F = 125000 + 10000$

Step 6 – evaluate: $F = 135000$ N $= 135$ kN

Final Answer: $F = 135$ kN $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – specific impulse: $I_{sp} = \dfrac{F}{\dot{m}\, g_0}$, the thrust per unit weight flow of propellant.

Step 1 – list the data: $F = 9810$ N, $\dot{m} = 5$ kg/s, $g_0 = 9.81$ m/s^2.

Step 2 – form the denominator $\dot{m}\, g_0$: $\dot{m}\, g_0 = 5 \times 9.81 = 49.05$

Step 3 – divide the thrust by that value: $I_{sp} = \dfrac{9810}{49.05}$

Step 4 – evaluate: $I_{sp} = 200$ s

Final Answer: $I_{sp} = 200$ s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q42

Q43.

Solution

Concept – Tsiolkovsky rocket equation: $\Delta v = I_{sp}\, g_0\, \ln\left(\dfrac{m_0}{m_f}\right)$.

Step 1 – list the data: $I_{sp} = 250$ s, $g_0 = 9.81$ m/s^2, $\dfrac{m_0}{m_f} = 2$.

Step 2 – form the effective exhaust velocity $I_{sp}\, g_0$: $I_{sp}\, g_0 = 250 \times 9.81 = 2452.5$ m/s

Step 3 – take the natural logarithm of the mass ratio: $\ln 2 = 0.6931$

Step 4 – multiply: $\Delta v = 2452.5 \times 0.6931$

Step 5 – evaluate: $\Delta v = 1700$ m/s

Final Answer: $\Delta v \approx 1700$ m/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) **Go Back to Q43**

Q44.

Solution

Concept – air–fuel ratio from equivalence ratio: Since $\phi = \dfrac{(A/F)_{\text{stoich}}}{(A/F)_{\text{actual}}}$, the actual ratio is $(A/F)_{\text{actual}} = \dfrac{(A/F)_{\text{stoich}}}{\phi}$.

Step 1 – list the data: $(A/F)_{\text{stoich}} = 15$, $\phi = 0.60$.

Step 2 – substitute into the formula: $(A/F)_{\text{actual}} = \dfrac{15}{0.60}$

Step 3 – evaluate: $(A/F)_{\text{actual}} = 25$

Step 4 – interpret: An air–fuel ratio of 25, larger than the stoichiometric 15, confirms a lean (excess-air) mixture, consistent with $\phi < 1$.

Final Answer: $(A/F)_{\text{actual}} = 25 \Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q44**

Q45.

Solution

Concept – overall efficiency of a jet engine: The overall efficiency is the product of propulsive and thermal efficiencies, $\eta_o = \eta_p\,\eta_{th}$.

Step 1 – list the data: $\eta_p = 0.50$, $\eta_{th} = 0.50$.

Step 2 – multiply the two efficiencies: $\eta_o = 0.50 \times 0.50$

Step 3 – evaluate: $\eta_o = 0.25$

Final Answer: $\eta_o = 0.25 \Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q45**

Q46.

Solution

Concept – isentropic expansion in a turbine: $\dfrac{T_{04}}{T_{03}} = r_p^{-(\gamma-1)/\gamma}$, so $T_{04} = T_{03}\, r_p^{-(\gamma-1)/\gamma}$.

Step 1 – list the data: $T_{03} = 1200$ K, $r_p = 8$, $\gamma = 1.4$.

Step 2 – form the exponent $\dfrac{\gamma - 1}{\gamma}$**:** $\dfrac{0.4}{1.4} = 0.2857$

Step 3 – raise the pressure ratio to that power: $8^{0.2857} = 1.8114$

Step 4 – divide the inlet temperature by that factor: $T_{04} = \dfrac{1200}{1.8114}$

Step 5 – evaluate: $T_{04} = 662.5 \text{ K} \approx 663 \text{ K}$

Final Answer: $T_{04} \approx 663 \text{ K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	C	4	A	5	D
6	B	7	C	8	B	9	D	10	D
11	A	12	B	13	A	14	C	15	D
16	A	17	C	18	A	19	A	20	B
21	A	22	D	23	D	24	C	25	B
26	B	27	D	28	A	29	C	30	D
31	C	32	A	33	C	34	B	35	D
36	B	37	C	38	B	39	D	40	B
41	A	42	A	43	B	44	D	45	C
46	A								