GATE Aerospace Engineering

Sample Paper – 9

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 cruises at a true airspeed of 255 m/s at an altitude where the static air temperature is 223.15 K. Taking $\gamma = 1.4$ and $R = 287$ J/kg · K, the flight Mach number is nearest to: **[1 mark]**

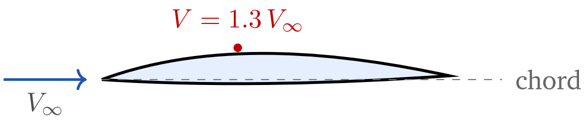
(A) 0.55

(B) 1.18

(C) 0.85

(D) 0.72

Q2. In the low-speed (incompressible) flow over the airfoil shown, the local velocity at a point on the upper surface is 1.3 times the freestream velocity. The pressure coefficient $\left(C_p = 1 - (V/V_\infty)^2\right)$ at that point is: **[1 mark]**



(A) $+0.69$

(B) -0.30

(C) $+0.30$

(D) -0.69

Q3. Air ($\gamma = 1.4$) flows isentropically at a Mach number of 0.8. The ratio of the stagnation (total) pressure to the static pressure, p_0/p, is nearest to: **[1 mark]**

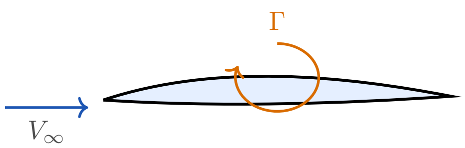
(A) 1.128

(B) 1.000

(C) 1.280

(D) 1.524

Q4. An airfoil section develops a bound circulation of $\Gamma = 20$ m^2/s in a stream of air ($\rho = 1.225$ kg/m^3) moving at 50 m/s, as shown. By the Kutta–Joukowski theorem, the lift per unit span is: **[1 mark]**



(A) 2450 N/m

(B) 1225 N/m

(C) 612.5 N/m

(D) 1000 N/m

Q5. A body of reference area 2 m^2 and drag coefficient 0.03 moves through sea-level air ($\rho = 1.225$ kg/m^3) at 50 m/s. The aerodynamic drag force on the body is nearest to: **[1 mark]**

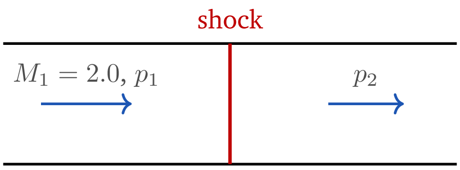
(A) 45.9 N

(B) 91.9 N

(C) 183.8 N

(D) 61.3 N

Q6. A normal shock stands in the duct shown with an upstream Mach number of 2.0 in air ($\gamma = 1.4$). The static-pressure ratio across the shock, $p_2/p_1 = 1 + \frac{2\gamma}{\gamma+1}(M_1^2 - 1)$, is: **[1 mark]**



(A) 1.5

(B) 2.5

(C) 3.5

(D) 4.5

Q7. Across a normal shock at an upstream Mach number of 2.0 in air ($\gamma = 1.4$), the density ratio $\frac{\rho_2}{\rho_1} = \frac{(\gamma+1)M_1^2}{(\gamma-1)M_1^2+2}$ is nearest to: **[1 mark]**

(A) 1.50

(B) 2.00

(C) 2.67

(D) 3.50

Q8. The incompressible pressure coefficient at a point on an airfoil is $C_{p,0} = -0.40$. Applying the Prandtl–Glauert compressibility correction $\left(C_p = C_{p,0}/\sqrt{1-M_\infty^2}\right)$ at a freestream Mach number of 0.6, the corrected pressure coefficient is: **[1 mark]**

(A) -0.50

(B) -0.32

(C) -0.40

(D) -0.64

Q9. Air flows over a flat plate at zero incidence, giving a fully laminar boundary layer over the whole plate. The Reynolds number based on the plate length is $Re_L = 10^6$. The average (total) skin-friction drag coefficient from the Blasius result $\left(C_f = 1.328/\sqrt{Re_L}\right)$ is: **[1 mark]**

(A) 5.31×10^{-3}

(B) 0.664×10^{-3}

(C) 2.66×10^{-3}

(D) 1.33×10^{-3}

Q10. A laminar boundary layer grows over a flat plate. At a station $x = 0.5$ m from the leading edge the local Reynolds number is 2.5×10^5. The Blasius displacement thickness $\left(\delta^* = 1.721\, x/\sqrt{Re_x}\right)$ is nearest to: **[1 mark]**

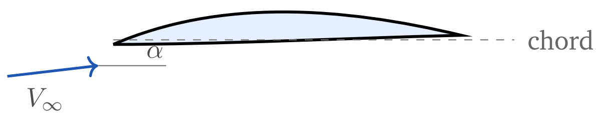
(A) 0.86 mm

(B) 5.0 mm

(C) 2.5 mm

(D) 1.72 mm

Q11. A thin cambered airfoil has a zero-lift angle of attack of -2° and is set at a geometric angle of attack of 4°, as shown. Using the thin-airfoil result $c_\ell = 2\pi(\alpha - \alpha_{L0})$ with angles in radians, the section lift coefficient is nearest to: **[1 mark]**



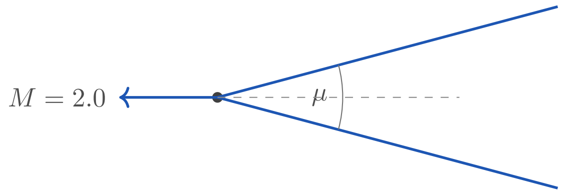
(A) 0.219

(B) 0.658

(C) 0.438

(D) 0.110

Q12. A slender body flies at a Mach number of 2.0, generating the Mach cone shown. The Mach angle $\left(\mu = \sin^{-1}(1/M)\right)$ is: **[1 mark]**



(A) 19.5°

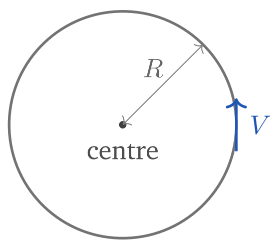
(B) 41.8°

(C) 30.0°

(D) 60.0°

Flight Mechanics & Space Dynamics

Q13. An aircraft flies a steady, level, co-ordinated turn at a true airspeed of 100 m/s and a bank angle of 45°, as shown in the top view. The radius of the turn $\left(R = V^2/(g \tan\phi)\right)$ is nearest to: **[1 mark]**



(A) 509.7 m

(B) 2039 m

(C) 1019 m

(D) 1470 m

Q14. An aircraft flies a steady, level turn at a true airspeed of 100 m/s and a bank angle of 30°. The turn rate $\left(\omega = g \tan \phi / V\right)$ is nearest to: **[1 mark]**

(A) 0.0566 rad/s

(B) 0.0283 rad/s

(C) 0.1132 rad/s

(D) 0.0980 rad/s

Q15. An aircraft of weight 50,000 N flies at 50 m/s. The engines deliver a thrust of 6000 N while the drag is 4000 N. The steady rate of climb $\left(R/C = (T - D)V/W\right)$ is: **[1 mark]**

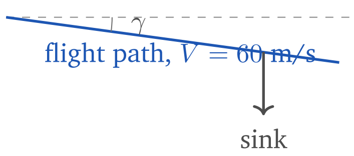
(A) 0.5 m/s

(B) 1.0 m/s

(C) 2.0 m/s

(D) 4.0 m/s

Q16. An aircraft descends in a steady, unpowered glide at a forward speed of 60 m/s with a lift-to-drag ratio of 20, as shown. The rate of descent (sink rate $\approx V/(L/D)$) is nearest to: **[1 mark]**



(A) 3.0 m/s

(B) 1.5 m/s

(C) 6.0 m/s

(D) 12.0 m/s

Q17. A tailplane is mounted a distance $l_t = 5$ m aft of the aircraft's centre of gravity and has a planform area $S_t = 3$ m^2. The wing has a mean aerodynamic chord $\bar{c} = 1.5$ m and a planform area $S = 20$ m^2. The horizontal-tail volume ratio $\big(V_H = l_t S_t/(\bar{c}\, S)\big)$ is: **[1 mark]**

(A) 0.25

(B) 1.00

(C) 0.50

(D) 0.75

Q18. For an airplane to possess directional (weathercock) static stability about the yaw axis, the yawing-moment characteristic with sideslip angle β must satisfy: **[1 mark]**

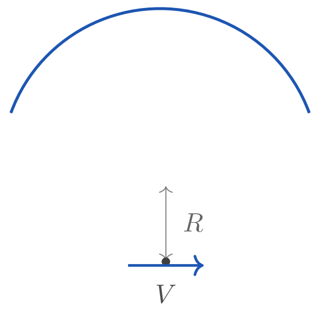
(A) $C_{n_\beta} > 0$

(B) $C_{n_\beta} < 0$

(C) $C_{n_\beta} = 0$

(D) $C_{l_\beta} > 0$

Q19. An aircraft pulls up out of a dive along a circular arc of radius 510 m at a speed of 100 m/s in the vertical plane, as shown. At the bottom of the arc the load factor $\big(n = 1 + V^2/(gR)\big)$ is nearest to: **[1 mark]**



(A) 2.0

(B) 3.0

(C) 4.0

(D) 1.0

Q20. An aircraft stalls in 1-g level flight at a speed of 50 m/s. In a steady, level turn its load factor rises to $n = 4$. The stalling speed in the turn $\left(V_{s,\text{turn}} = V_s\sqrt{n}\right)$ is: **[1 mark]**

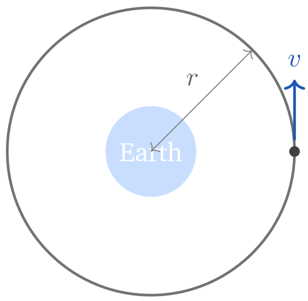
(A) 50 m/s

(B) 25 m/s

(C) 100 m/s

(D) 70.7 m/s

Q21. A satellite is in a circular orbit of radius 7000 km about the Earth, as shown. Taking $\mu = 3.986 \times 10^{14}$ m^3/s^2, the orbital period $\left(T = 2\pi\sqrt{a^3/\mu}\right)$ is nearest to: **[2 marks]**



(A) 3600 s

(B) 5829 s

(C) 8382 s

(D) 4919 s

Q22. A geostationary satellite orbits the Earth in a circular orbit of radius 42,164 km. Taking $\mu = 3.986 \times 10^{14}$ m^3/s^2, the orbital speed $\left(v = \sqrt{\mu/r}\right)$ is nearest to: **[2 marks]**

(A) 7.91 km/s

(B) 3.07 km/s

(C) 11.2 km/s

(D) 1.02 km/s

Q23. A satellite moves in an elliptic orbit about the Earth with a semi-major axis of 10,000 km. Taking $\mu = 3.986 \times 10^{14}$ m^3/s^2, the specific orbital energy $\left(\varepsilon = -\mu/(2a)\right)$ is nearest to: **[2 marks]**

(A) -19.9 MJ/kg

(B) -39.9 MJ/kg

(C) -9.97 MJ/kg

(D) -3.99 MJ/kg

Aerospace Structures

Q24. A straight bar of length 2 m and cross-sectional area 600 mm^2 is made of a material with Young's modulus 200 GPa and carries an axial tensile load of 60 kN. The elongation of the bar $\left(\delta = PL/AE\right)$ is: **[2 marks]**

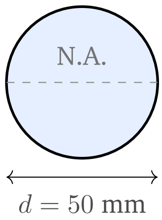
(A) 0.5 mm

(B) 1.0 mm

(C) 2.0 mm

(D) 1.5 mm

Q25. 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 stress $\left(\sigma = 32M/(\pi d^3)\right)$ is nearest to: **[2 marks]**



(A) 81.5 MPa

(B) 326 MPa

(C) 163 MPa

(D) 122 MPa

Q26. 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. The angle of twist $\left(\theta = TL/GJ,\ J = \pi d^4/32\right)$ is nearest to: **[2 marks]**

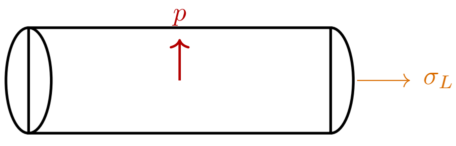
(A) 1.42°

(B) 2.85°

(C) 0.71°

(D) 0.36°

Q27. A thin-walled cylindrical pressure vessel of internal diameter 1.2 m and wall thickness 12 mm carries an internal gauge pressure of 3 MPa, as shown. The longitudinal (axial) stress in the wall $\left(\sigma_L = pd/4t\right)$ is: **[2 marks]**



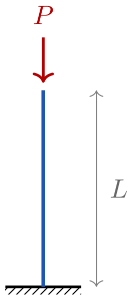
(A) 150 MPa

(B) 75 MPa

(C) 37.5 MPa

(D) 100 MPa

Q28. The fixed–free (cantilever) column shown has a length of 2 m, a second moment of area of 2×10^6 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]**



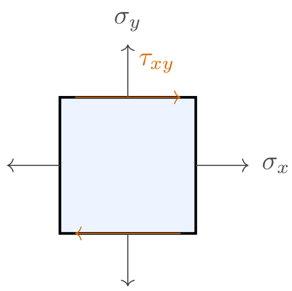
(A) 987 kN

(B) 493 kN

(C) 123 kN

(D) 247 kN

Q29. At a point in a loaded member the plane-stress components are $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa and $\tau_{xy} = 30$ MPa, as shown on the stress element. The major principal stress $\left(\sigma_1 = \frac{\sigma_x+\sigma_y}{2} + \sqrt{(\frac{\sigma_x-\sigma_y}{2})^2 + \tau_{xy}^2}\right)$ is nearest to: **[2 marks]**



(A) 112.4 MPa

(B) 27.6 MPa

(C) 70.0 MPa

(D) 142.4 MPa

Q30. At a point in a structural member the direct stress is 200 MPa and the material has Young's modulus 200 GPa. The strain-energy density (energy stored per unit volume, $u = \sigma^2/2E$) is: **[2 marks]**

(A) 50 kJ/m^3

(B) 100 kJ/m^3

(C) 200 kJ/m^3

(D) 25 kJ/m^3

Q31. A single-degree-of-freedom system has a mass of 2 kg, a stiffness of 800 N/m and a viscous damping coefficient of 40 N · s/m. The damping ratio $\left(\zeta = c/(2\sqrt{km})\right)$ is: **[2 marks]**

(A) 0.25

(B) 1.00

(C) 0.50

(D) 0.707

Q32. A beam of solid rectangular cross-section with area 1500 mm^2 carries a transverse shear force of 30 kN at a section. The maximum transverse shear stress $\left(\tau_{\max} = 1.5\,V/A\right)$ is: **[2 marks]**

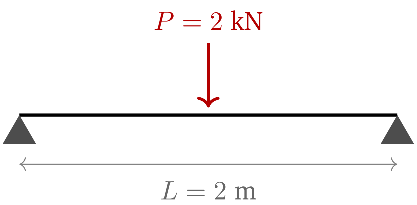
(A) 20 MPa

(B) 15 MPa

(C) 10 MPa

(D) 30 MPa

Q33. The simply supported beam shown spans 2 m and carries a central point load of 2 kN. The beam has $E = 200$ GPa and $I = 4 \times 10^6$ 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) 0.83 mm

(D) 0.417 mm

Q34. An aluminium bar ($E = 70$ GPa, coefficient of thermal expansion $\alpha = 23 \times 10^{-6}$ K^{-1}) is fully restrained between two rigid walls and heated uniformly by 50 K. The magnitude of the induced thermal stress $\left(\sigma = E\alpha\,\Delta T\right)$ is nearest to: **[2 marks]**

(A) 40.3 MPa

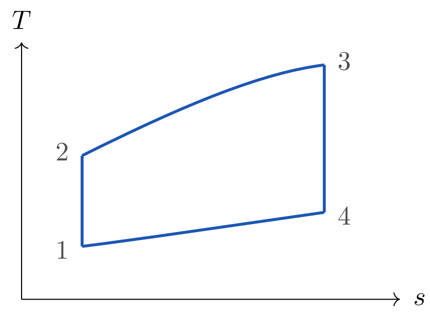
(B) 80.5 MPa

(C) 161 MPa

(D) 23.0 MPa

Propulsion

Q35. An ideal (air-standard) Brayton cycle operates with a compressor pressure ratio of 16 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) 37.5%

(B) 44.8%

(C) 54.7%

(D) 50.0%

Q36. A turbojet ingests air at 40 kg/s. The flight (inlet) velocity is 250 m/s and the exhaust jet velocity is 600 m/s. Neglecting the fuel mass flow and pressure-thrust terms, the net thrust $\left(F = \dot{m}(V_e - V_0)\right)$ is: **[2 marks]**

(A) 14 kN

(B) 24 kN

(C) 10 kN

(D) 34 kN

Q37. In a gas-turbine combustor the air enters at a stagnation temperature such that heat is added at a rate giving a specific heat release of 600 kJ/kg of air. Taking $c_p = 1.005$ kJ/kg · K, the stagnation-temperature rise across the combustor $\left(\Delta T = q/c_p\right)$ is nearest to: **[2 marks]**

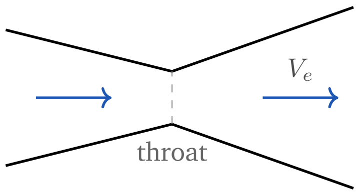
(A) 1005 K

(B) 300 K

(C) 500 K

(D) 597 K

Q38. Air expands through the convergent–divergent nozzle shown from a chamber where the velocity is negligible. The static temperature drops by 300 K from chamber to exit. 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) 549 m/s

(B) 776 m/s

(C) 634 m/s

(D) 388 m/s

Q39. Air ($\gamma = 1.4$) expands through a nozzle until the flow 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 nearest to: **[2 marks]**

(A) 0.528

(B) 0.634

(C) 0.913

(D) 0.833

Q40. In an axial-flow gas turbine stage the stagnation temperature of the gas drops by 150 K across the rotor. Taking $c_p = 1005$ J/kg · K, the specific work output $\left(w = c_p\,\Delta T_0\right)$ is nearest to: **[2 marks]**

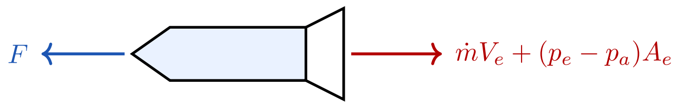
(A) 151 kJ/kg

(B) 75 kJ/kg

(C) 300 kJ/kg

(D) 100 kJ/kg

Q41. A rocket engine expels propellant at 200 kg/s with an exhaust velocity of 2500 m/s. The nozzle is under-expanded, so the exit-plane pressure exceeds ambient by 50 kPa acting over an exit area of 0.2 m^2, as shown. The thrust $\left(F = \dot{m}V_e + (p_e - p_a)A_e\right)$ is: **[2 marks]**



(A) 510 kN

(B) 500 kN

(C) 10 kN

(D) 490 kN

Q42. A rocket engine produces a thrust of 200 kN while expelling propellant at a mass flow rate of 80 kg/s. Taking $g_0 = 9.81$ m/s^2, the specific impulse $\left(I_{sp} = F/(\dot{m}\, g_0)\right)$ is nearest to: **[2 marks]**

(A) 288 s

(B) 350 s

(C) 255 s

(D) 300 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 4. 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) 2452 m/s

(B) 3400 m/s

(C) 6931 m/s

(D) 1699 m/s

Q44. A gas-turbine combustor burns a hydrocarbon fuel whose stoichiometric air–fuel ratio is 15. The mixture supplied is rich with an equivalence ratio of 1.25. The actual air–fuel ratio $\left((A/F)_{\text{actual}} = (A/F)_{\text{stoich}}/\phi\right)$ is: [2 marks]

(A) 18.75

(B) 15.0

(C) 16.7

(D) 12.0

Q45. A turbojet has a thermal efficiency of 0.50 and a propulsive efficiency of 0.60. The overall efficiency of the engine $\left(\eta_0 = \eta_{th}\,\eta_p\right)$ is: [2 marks]

(A) 0.30

(B) 0.55

(C) 0.11

(D) 0.83

Q46. Hot gas enters a turbine at a stagnation temperature of 1200 K and expands isentropically through a pressure ratio of 5 ($\gamma = 1.4$). The turbine-exit stagnation temperature $\left(T_{02} = T_{01}\,r_p^{-(\gamma-1)/\gamma}\right)$ is nearest to: [2 marks]

(A) 758 K

(B) 1200 K

(C) 900 K

(D) 600 K

Detailed Solutions

Q1.

Solution

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

Step 1 – list the data: $V = 255$ m/s, $T = 223.15$ 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: $\gamma RT = 401.8 \times 223.15 = 89661.7$

Step 4 – take the square root to get the speed of sound: $a = \sqrt{89661.7} = 299.4$ m/s

Step 5 – divide the airspeed by the speed of sound: $M = \dfrac{255}{299.4}$

Step 6 – evaluate: $M = 0.852 \approx 0.85$

Final Answer: $M \approx 0.85 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – incompressible pressure coefficient: $C_p = 1 - \left(\dfrac{V}{V_\infty}\right)^2$; a point where the flow speeds up has a negative C_p.

Step 1 – list the data: $\dfrac{V}{V_\infty} = 1.3$.

Step 2 – square the velocity ratio: $\left(\dfrac{V}{V_\infty}\right)^2 = 1.3^2 = 1.69$

Step 3 – substitute into the formula: $C_p = 1 - 1.69$

Step 4 – evaluate: $C_p = -0.69$

Step 5 – interpret the sign: The negative value confirms a suction (below freestream) pressure where the flow accelerates.

Final Answer: $C_p = -0.69 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – isentropic stagnation-to-static pressure ratio: $\frac{p_0}{p} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\gamma/(\gamma-1)}$.

Step 1 – list the data: $\gamma = 1.4$, $M = 0.8$.

Step 2 – evaluate $\frac{\gamma - 1}{2}$**:** $\frac{1.4 - 1}{2} = \frac{0.4}{2} = 0.2$

Step 3 – square the Mach number: $M^2 = 0.8^2 = 0.64$

Step 4 – form the bracket: $1 + 0.2 \times 0.64 = 1 + 0.128 = 1.128$

Step 5 – form the exponent: $\frac{\gamma}{\gamma - 1} = \frac{1.4}{0.4} = 3.5$

Step 6 – raise the bracket to the exponent: $\frac{p_0}{p} = 1.128^{3.5}$

$\frac{p_0}{p} = 1.524$

Final Answer: $\frac{p_0}{p} \approx 1.524 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – Kutta–Joukowski theorem: The lift per unit span is $L' = \rho V_\infty \Gamma$.

Step 1 – list the data: $\rho = 1.225\ \text{kg/m}^3$, $V_\infty = 50$ m/s, $\Gamma = 20\ \text{m}^2/\text{s}$.

Step 2 – multiply density by velocity: $\rho V_\infty = 1.225 \times 50 = 61.25$

Step 3 – multiply by the circulation: $L' = 61.25 \times 20$

Step 4 – evaluate: $L' = 1225$ N/m

Final Answer: $L' = 1225\ \text{N/m} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – drag force from the drag coefficient: $D = \frac{1}{2}\rho V^2 S\, C_D$.

Step 1 – list the data: $\rho = 1.225\ \text{kg/m}^3$, $V = 50$ m/s, $S = 2\ \text{m}^2$, $C_D = 0.03$.

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

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

$q = 0.6125 \times 2500 = 1531.25$ Pa

Step 4 – multiply by the area: $q\,S = 1531.25 \times 2 = 3062.5$ N

Step 5 – multiply by the drag coefficient: $D = 3062.5 \times 0.03$

Step 6 – evaluate: $D = 91.875 \approx 91.9$ N

Final Answer: $D \approx 91.9 \text{ N} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

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

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

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

Step 3 – evaluate $M_1^2 - 1$**:** $2.0^2 - 1 = 4 - 1 = 3$

Step 4 – multiply the coefficient by $(M_1^2 - 1)$**:** $1.1667 \times 3 = 3.5$

Step 5 – add 1: $\dfrac{p_2}{p_1} = 1 + 3.5 = 4.5$

Final Answer: $\dfrac{p_2}{p_1} = 4.5 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – density ratio across a normal shock: $\dfrac{\rho_2}{\rho_1} = \dfrac{(\gamma+1)M_1^2}{(\gamma-1)M_1^2 + 2}$.

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

Step 2 – evaluate the numerator: $(\gamma+1)M_1^2 = 2.4 \times 4 = 9.6$

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

$1.6 + 2 = 3.6$

Step 4 – form the ratio: $\dfrac{\rho_2}{\rho_1} = \dfrac{9.6}{3.6}$

Step 5 – evaluate: $\dfrac{\rho_2}{\rho_1} = 2.667$

Final Answer: $\frac{\rho_2}{\rho_1} \approx 2.67 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – Prandtl–Glauert compressibility correction: $C_p = \dfrac{C_{p,0}}{\sqrt{1 - M_\infty^2}}$.

Step 1 – list the data: $C_{p,0} = -0.40$, $M_\infty = 0.6$.

Step 2 – square the Mach number: $M_\infty^2 = 0.6^2 = 0.36$

Step 3 – form $1 - M_\infty^2$**:** $1 - 0.36 = 0.64$

Step 4 – take the square root: $\sqrt{0.64} = 0.8$

Step 5 – divide the incompressible value by the root: $C_p = \dfrac{-0.40}{0.8}$

Step 6 – evaluate: $C_p = -0.50$

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

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – Blasius average skin-friction drag coefficient: Integrating the local wall shear over a laminar flat plate gives the average (total) skin-friction coefficient $C_f = \dfrac{1.328}{\sqrt{Re_L}}$, which is exactly twice the local c_f evaluated at the trailing edge.

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

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

Step 3 – substitute into the formula: $C_f = \dfrac{1.328}{1000}$

Step 4 – evaluate: $C_f = 1.328 \times 10^{-3}$

Step 5 – round: $C_f \approx 1.33 \times 10^{-3}$

Step 6 – note the common trap: The value 0.664×10^{-3} is the *local* coefficient at the trailing edge; the question asks for the plate *average*, which is twice as large.

Final Answer: $C_f = 1.33 \times 10^{-3} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – Blasius displacement thickness: $\delta^* = \dfrac{1.721\,x}{\sqrt{Re_x}}$.

Step 1 – list the data: $x = 0.5$ m, $Re_x = 2.5 \times 10^5$.

Step 2 – take the square root of the Reynolds number: $\sqrt{2.5 \times 10^5} = 500$

Step 3 – form the numerator: $1.721 \times 0.5 = 0.8605$

Step 4 – divide by the root: $\delta^* = \dfrac{0.8605}{500}$

Step 5 – evaluate: $\delta^* = 1.721 \times 10^{-3}$ m

Step 6 – convert to millimetres: $\delta^* = 1.72$ mm

Final Answer: $\delta^* \approx 1.72$ mm $\Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q10**

Q11.

Solution

Concept – thin-airfoil lift coefficient with camber: $c_\ell = 2\pi(\alpha - \alpha_{L0})$, with angles in radians.

Step 1 – list the data: $\alpha = 4°$, $\alpha_{L0} = -2°$.

Step 2 – form the effective angle: $\alpha - \alpha_{L0} = 4° - (-2°) = 6°$

Step 3 – convert to radians: $6° = 6 \times \dfrac{\pi}{180}$

$= 6 \times 0.017453$

$= 0.10472$ rad

Step 4 – multiply by 2π: $c_\ell = 2\pi \times 0.10472$

$c_\ell = 6.2832 \times 0.10472$

Step 5 – evaluate: $c_\ell = 0.658$

Final Answer: $c_\ell \approx 0.658 \Rightarrow \boxed{\text{B}}$

Answer: (B) **Go Back to Q11**

Q12.

Solution

Concept – Mach angle: The half-angle of the Mach cone is $\mu = \sin^{-1}\left(\frac{1}{M}\right)$.

Step 1 – list the data: $M = 2.0$.

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

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

Step 4 – evaluate: $\mu = 30°$

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

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – radius of a level, co-ordinated turn: $R = \frac{V^2}{g\tan\phi}$.

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

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: $R = 1019.4 \approx 1019$ m

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

Answer: (C) Go Back to Q13

Q14.

Solution

Concept – turn rate of a level turn: $\omega = \frac{g\tan\phi}{V}$.

Step 1 – list the data: $g = 9.81$ m/s^2, $\phi = 30°$, $V = 100$ m/s.

Step 2 – evaluate $\tan\phi$: $\tan 30° = 0.57735$

Step 3 – form the numerator: $g\tan\phi = 9.81 \times 0.57735 = 5.6638$

Step 4 – divide by the velocity: $\omega = \frac{5.6638}{100}$

Step 5 – evaluate: $\omega = 0.0566$ rad/s

Final Answer: $\omega \approx 0.0566$ rad/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – steady rate of climb: The rate of climb is $R/C = \dfrac{(T-D)V}{W}$, where $T - D$ is the excess thrust.

Step 1 – list the data: $T = 6000$ N, $D = 4000$ N, $V = 50$ m/s, $W = 50000$ N.

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

Step 3 – multiply by the velocity (excess power): $(T-D)V = 2000 \times 50 = 100000$ W

Step 4 – divide by the weight: $R/C = \dfrac{100000}{50000}$

Step 5 – evaluate: $R/C = 2.0$ m/s

Final Answer: $R/C = 2.0$ m/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – sink rate in a steady glide: For a shallow glide the flight-path angle is small, so the sink rate is $V_s \approx \dfrac{V}{L/D}$.

Step 1 – list the data: $V = 60$ m/s, $L/D = 20$.

Step 2 – divide the forward speed by the glide ratio: $V_s = \dfrac{60}{20}$

Step 3 – evaluate: $V_s = 3.0$ m/s

Step 4 – interpret: A higher L/D would reduce the sink rate for the same forward speed.

Final Answer: $V_s = 3.0$ m/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – horizontal-tail volume ratio: $V_H = \dfrac{l_t\,S_t}{\bar{c}\,S}$.

Step 1 – list the data: $l_t = 5$ m, $S_t = 3$ m^2, $\bar{c} = 1.5$ m, $S = 20$ m^2.

Step 2 – form the numerator: $l_t S_t = 5 \times 3 = 15$

Step 3 – form the denominator: $\bar{c}\,S = 1.5 \times 20 = 30$

Step 4 – divide: $V_H = \dfrac{15}{30}$

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 statically stable aircraft must develop a restoring yawing moment when it sideslips: if it yaws nose-right (positive β), a positive (nose-left restoring) yawing moment is needed.

Step 1 – state the stability derivative: The yawing-moment-with-sideslip derivative is $C_{n_\beta} = \dfrac{\partial C_n}{\partial \beta}$.

Step 2 – apply the restoring-moment requirement: For the moment to oppose the disturbance, C_{n_β} must be positive.

Step 3 – eliminate the wrong options: $C_{n_\beta} < 0$ is destabilising; $C_{n_\beta} = 0$ is neutral; $C_{l_\beta} > 0$ describes rolling (lateral), not directional, behaviour.

Final Answer: $C_{n_\beta} > 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q18

Q19.

Solution

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

Step 1 – list the data: $V = 100$ m/s, $R = 510$ m, $g = 9.81$ m/s^2.

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

Step 3 – form the denominator: $gR = 9.81 \times 510 = 5003.1$

Step 4 – form the centripetal term: $\dfrac{V^2}{gR} = \dfrac{10000}{5003.1} = 1.999$

Step 5 – add 1: $n = 1 + 1.999 = 2.999 \approx 3.0$

Final Answer: $n \approx 3.0 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – stalling speed in a turn: Because lift must equal nW at the stall, the turning stall speed scales as $V_{s,\text{turn}} = V_s\sqrt{n}$.

Step 1 – list the data: $V_s = 50$ m/s, $n = 4$.

Step 2 – take the square root of the load factor: $\sqrt{4} = 2$

Step 3 – multiply the level stall speed by that root: $V_{s,\text{turn}} = 50 \times 2$

Step 4 – evaluate: $V_{s,\text{turn}} = 100$ m/s

Final Answer: $V_{s,\text{turn}} = 100$ m/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q20

Q21.

Solution

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

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: $\dfrac{a^3}{\mu} = \dfrac{3.43 \times 10^{20}}{3.986 \times 10^{14}} = 8.605 \times 10^5$

Step 4 – take the square root: $\sqrt{8.605 \times 10^5} = 927.6$

Step 5 – multiply by 2π: $T = 2\pi \times 927.6$

$T = 6.2832 \times 927.6$

Step 6 – evaluate: $T = 5828.7 \approx 5829$ s

Final Answer: $T \approx 5829$ s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – circular orbital speed: $v = \sqrt{\dfrac{\mu}{r}}$.

Step 1 – list the data: $r = 42164$ km $= 4.2164 \times 10^7$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – divide μ by r: $\dfrac{\mu}{r} = \dfrac{3.986 \times 10^{14}}{4.2164 \times 10^7}$

$= 9.454 \times 10^6$

Step 3 – take the square root: $v = \sqrt{9.454 \times 10^6}$

$v = 3074.7$ m/s

Step 4 – convert to km/s: $v = 3.07$ km/s

Final Answer: $v \approx 3.07$ km/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – specific orbital energy: For any Keplerian orbit $\varepsilon = -\dfrac{\mu}{2a}$.

Step 1 – list the data: $a = 10000$ km $= 1 \times 10^7$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – form the denominator $2a$: $2a = 2 \times 1 \times 10^7 = 2 \times 10^7$

Step 3 – divide μ by $2a$: $\dfrac{\mu}{2a} = \dfrac{3.986 \times 10^{14}}{2 \times 10^7} = 1.993 \times 10^7$

Step 4 – apply the negative sign: $\varepsilon = -1.993 \times 10^7$ J/kg

Step 5 – express in MJ/kg: $\varepsilon = -19.93 \approx -19.9$ MJ/kg

Final Answer: $\varepsilon \approx -19.9$ MJ/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

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

Step 1 – list the data: $P = 60$ kN $= 60 \times 10^3$ N, $L = 2$ m, $A = 600$ mm^2 $= 600 \times 10^{-6}$ m^2, $E = 200$ GPa $= 200 \times 10^9$ Pa.

Step 2 – form the numerator PL: $PL = 60 \times 10^3 \times 2 = 1.2 \times 10^5$

Step 3 – form the denominator AE: $AE = 600 \times 10^{-6} \times 200 \times 10^9$

$= 1.2 \times 10^8$

Step 4 – divide: $\delta = \dfrac{1.2 \times 10^5}{1.2 \times 10^8}$

Step 5 – evaluate: $\delta = 1 \times 10^{-3}$ m

Step 6 – convert to millimetres: $\delta = 1.0$ mm

Final Answer: $\delta = 1.0 \text{ mm} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

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

Step 1 – list the data: $M = 2$ kN·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: $\sigma \approx 163 \text{ MPa} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

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

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 second moment: $J = \dfrac{\pi \times 2.56 \times 10^{-6}}{32}$

$J = \dfrac{8.042 \times 10^{-6}}{32} = 2.513 \times 10^{-7}$ 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: $\theta = 0.02487 \times \dfrac{180}{\pi} = 1.425°$

Final Answer: $\theta \approx 1.42° \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

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

Step 1 – list the data: $p = 3$ MPa $= 3 \times 10^6$ Pa, $d = 1.2$ m, $t = 12$ mm $= 0.012$ m.

Step 2 – form the numerator pd: $pd = 3 \times 10^6 \times 1.2 = 3.6 \times 10^6$

Step 3 – form the denominator $4t$: $4t = 4 \times 0.012 = 0.048$

Step 4 – divide: $\sigma_L = \dfrac{3.6 \times 10^6}{0.048}$

Step 5 – evaluate: $\sigma_L = 7.5 \times 10^7$ Pa $= 75$ MPa

Final Answer: $\sigma_L = 75$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – Euler buckling of a fixed–free column: The critical load is $P_{cr} = \dfrac{\pi^2 EI}{(2L)^2} = \dfrac{\pi^2 EI}{4L^2}$, because the effective length is $2L$.

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

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

Step 3 – multiply by π^2: $\pi^2 EI = 9.8696 \times 4 \times 10^5 = 3.9478 \times 10^6$

Step 4 – form the denominator $4L^2$: $4L^2 = 4 \times 2^2 = 4 \times 4 = 16$

Step 5 – divide: $P_{cr} = \dfrac{3.9478 \times 10^6}{16}$

Step 6 – evaluate: $P_{cr} = 246740$ N ≈ 247 kN

Final Answer: $P_{cr} \approx 247$ kN $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – major principal stress in plane stress: $\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$.

Step 1 – list the data: $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa, $\tau_{xy} = 30$ 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 – square the two terms under the root: $30^2 = 900$

$\tau_{xy}^2 = 30^2 = 900$

Step 5 – add and take the square root (radius): $R = \sqrt{900 + 900} = \sqrt{1800} = 42.43$ MPa

Step 6 – add the average to the radius: $\sigma_1 = 70 + 42.43 = 112.43$ MPa

Final Answer: $\sigma_1 \approx 112.4$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – strain-energy density: $u = \frac{\sigma^2}{2E}$ (energy stored per unit volume).

Step 1 – list the data: $\sigma = 200$ MPa $= 200 \times 10^6$ Pa, $E = 200$ GPa $= 200 \times 10^9$ Pa.

Step 2 – square the stress: $\sigma^2 = (200 \times 10^6)^2 = 4 \times 10^{16}$

Step 3 – form the denominator $2E$: $2E = 2 \times 200 \times 10^9 = 4 \times 10^{11}$

Step 4 – divide: $u = \frac{4 \times 10^{16}}{4 \times 10^{11}}$

Step 5 – evaluate: $u = 1 \times 10^5$ J/m^3 $= 100$ kJ/m^3

Final Answer: $u = 100$ kJ/m^3 $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – damping ratio of an SDOF system: $\zeta = \dfrac{c}{2\sqrt{km}}$, where $2\sqrt{km}$ is the critical damping coefficient.

Step 1 – list the data: $m = 2$ kg, $k = 800$ N/m, $c = 40$ N · s/m.

Step 2 – form the product km: $km = 800 \times 2 = 1600$

Step 3 – take the square root: $\sqrt{1600} = 40$

Step 4 – form the critical damping coefficient: $c_c = 2\sqrt{km} = 2 \times 40 = 80$

Step 5 – divide the actual damping by the critical damping: $\zeta = \dfrac{40}{80}$

Step 6 – evaluate: $\zeta = 0.50$

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

Answer: (C) **Go Back to Q31**

Q32.

Solution

Concept – maximum transverse shear stress in a rectangle: For a rectangular section the peak (neutral-axis) shear stress is $\tau_{\max} = \dfrac{3}{2}\dfrac{V}{A} = 1.5\dfrac{V}{A}$.

Step 1 – list the data: $V = 30$ kN $= 30 \times 10^3$ N, $A = 1500$ mm^2 $= 1500 \times 10^{-6}$ m^2.

Step 2 – form the mean shear stress V/A: $\dfrac{V}{A} = \dfrac{30 \times 10^3}{1500 \times 10^{-6}}$ $= 2 \times 10^7$ Pa

Step 3 – multiply by 1.5: $\tau_{\max} = 1.5 \times 2 \times 10^7$

Step 4 – evaluate: $\tau_{\max} = 3 \times 10^7$ Pa $= 30$ MPa

Final Answer: $\tau_{\max} = 30$ MPa $\Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q32**

Q33.

Solution

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

Step 1 – list the data: $P = 2$ kN $= 2000$ N, $L = 2$ m, $E = 200$ GPa $= 200 \times 10^9$ Pa, $I = 4 \times 10^6$ mm^4 $= 4 \times 10^{-6}$ m^4.

Step 2 – cube the span: $L^3 = 2^3 = 8\ \text{m}^3$

Step 3 – form the numerator PL^3**:** $PL^3 = 2000 \times 8 = 16000$

Step 4 – form the product EI**:** $EI = 200 \times 10^9 \times 4 \times 10^{-6} = 8 \times 10^5$

Step 5 – form the denominator $48EI$**:** $48EI = 48 \times 8 \times 10^5 = 3.84 \times 10^7$

Step 6 – divide and convert: $\delta = \dfrac{16000}{3.84 \times 10^7} = 4.167 \times 10^{-4}\ \text{m} = 0.417\ \text{mm}$

Final Answer: $\delta \approx 0.417\ \text{mm} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q33

Q34.

Solution

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

Step 1 – list the data: $E = 70\ \text{GPa} = 70 \times 10^9\ \text{Pa}$, $\alpha = 23 \times 10^{-6}\ \text{K}^{-1}$, $\Delta T = 50\ \text{K}$.

Step 2 – form the product $\alpha\,\Delta T$ **(the prevented strain):** $\alpha\,\Delta T = 23 \times 10^{-6} \times 50 = 1.15 \times 10^{-3}$

Step 3 – multiply by Young's modulus: $\sigma = 70 \times 10^9 \times 1.15 \times 10^{-3}$

Step 4 – evaluate: $\sigma = 8.05 \times 10^7\ \text{Pa} = 80.5\ \text{MPa}$

Final Answer: $\sigma \approx 80.5\ \text{MPa} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

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

Step 1 – list the data: $r_p = 16$, $\gamma = 1.4$.

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: $16^{0.2857} = 2.2083$

Step 4 – take the reciprocal: $\dfrac{1}{2.2083} = 0.4528$

Step 5 – subtract from 1: $\eta = 1 - 0.4528 = 0.5472$

Step 6 – express as a percentage: $\eta = 54.7\%$

Final Answer: $\eta \approx 54.7\% \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – net thrust of a turbojet: Neglecting fuel mass and pressure terms, $F = \dot{m}(V_e - V_0)$.

Step 1 – list the data: $\dot{m} = 40$ kg/s, $V_e = 600$ m/s, $V_0 = 250$ m/s.

Step 2 – form the velocity difference: $V_e - V_0 = 600 - 250 = 350$ m/s

Step 3 – multiply by the mass flow: $F = 40 \times 350$

Step 4 – evaluate: $F = 14000$ N

Step 5 – convert to kN: $F = 14$ kN

Final Answer: $F = 14$ kN $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept – temperature rise from heat addition: For steady-flow heat addition at constant pressure, $q = c_p\,\Delta T$, so $\Delta T = q/c_p$.

Step 1 – list the data: $q = 600$ kJ/kg, $c_p = 1.005$ kJ/kg $\cdot$ K.

Step 2 – divide the heat release by c_p: $\Delta T = \dfrac{600}{1.005}$

Step 3 – evaluate: $\Delta T = 597.0$ K

Final Answer: $\Delta T \approx 597$ K $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – exit velocity from energy conservation: With negligible inlet velocity, $\frac{1}{2}V_e^2 = c_p\,\Delta T$, so $V_e = \sqrt{2c_p\,\Delta T}$.

Step 1 – list the data: $c_p = 1005$ J/kg $\cdot$ K, $\Delta T = 300$ K.

Step 2 – form the product $2c_p\,\Delta T$: $2 \times 1005 \times 300$

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

$2010 \times 300 = 603000$

Step 4 – take the square root: $V_e = \sqrt{603000}$

Step 5 – evaluate: $V_e = 776.5$ m/s

Final Answer: $V_e \approx 776$ m/s $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – choked (sonic) temperature ratio: Setting $M = 1$ in $\frac{T_0}{T} = 1 + \frac{\gamma - 1}{2}M^2$ gives $\frac{T^*}{T_0} = \frac{2}{\gamma + 1}$.

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

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

Step 3 – form the ratio: $\frac{T^*}{T_0} = \frac{2}{2.4}$

Step 4 – evaluate: $\frac{T^*}{T_0} = 0.8333$

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

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – turbine specific work: The specific work output equals the stagnation-enthalpy drop, $w = c_p\,\Delta T_0$.

Step 1 – list the data: $c_p = 1005$ J/kg · K, $\Delta T_0 = 150$ K.

Step 2 – multiply: $w = 1005 \times 150$

Step 3 – evaluate: $w = 150750$ J/kg

Step 4 – convert to kJ/kg: $w = 150.75 \approx 151$ kJ/kg

Final Answer: $w \approx 151$ kJ/kg $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – rocket thrust with a pressure term: $F = \dot{m}V_e + (p_e - p_a)A_e$; the momentum term plus the pressure-thrust term.

Step 1 – list the data: $\dot{m} = 200$ kg/s, $V_e = 2500$ m/s, $(p_e - p_a) = 50$ kPa $= 50 \times 10^3$ Pa, $A_e = 0.2$ m^2.

Step 2 – form the momentum thrust: $\dot{m}V_e = 200 \times 2500 = 500000$ N

Step 3 – form the pressure thrust: $(p_e - p_a)A_e = 50 \times 10^3 \times 0.2 = 10000$ N

Step 4 – add the two contributions: $F = 500000 + 10000 = 510000$ N

Step 5 – convert to kN: $F = 510$ kN

Final Answer: $F = 510 \text{ kN} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – specific impulse from thrust and mass flow: $I_{sp} = \dfrac{F}{\dot{m}\, g_0}$.

Step 1 – list the data: $F = 200$ kN $= 200 \times 10^3$ N, $\dot{m} = 80$ kg/s, $g_0 = 9.81$ m/s^2.

Step 2 – form the denominator $\dot{m}\, g_0$: $\dot{m}\, g_0 = 80 \times 9.81 = 784.8$

Step 3 – divide the thrust by that product: $I_{sp} = \dfrac{200 \times 10^3}{784.8}$

Step 4 – evaluate: $I_{sp} = 254.8$ s

Final Answer: $I_{sp} \approx 255 \text{ s} \Rightarrow \boxed{\text{C}}$

Answer: (C) 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, $\dfrac{m_0}{m_f} = 4$.

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 log of the mass ratio: $\ln 4 = 1.3863$

Step 4 – multiply: $\Delta v = 2452.5 \times 1.3863$

Step 5 – evaluate: $\Delta v = 3400$ m/s

Final Answer: $\Delta v \approx 3400$ m/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q43

Q44.

Solution

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

Step 1 – list the data: $(A/F)_{\text{stoich}} = 15$, $\phi = 1.25$.

Step 2 – divide the stoichiometric ratio by ϕ: $(A/F)_{\text{actual}} = \dfrac{15}{1.25}$

Step 3 – evaluate: $(A/F)_{\text{actual}} = 12$

Step 4 – interpret: Since $\phi > 1$, less air is supplied than stoichiometric, so the mixture is rich, consistent with a lower air–fuel ratio.

Final Answer: $(A/F)_{\text{actual}} = 12 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – overall efficiency of a jet engine: The overall efficiency is the product of the thermal and propulsive efficiencies, $\eta_0 = \eta_{th}\,\eta_p$.

Step 1 – list the data: $\eta_{th} = 0.50$, $\eta_p = 0.60$.

Step 2 – multiply the two efficiencies: $\eta_0 = 0.50 \times 0.60$

Step 3 – evaluate: $\eta_0 = 0.30$

Final Answer: $\eta_0 = 0.30 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – isentropic turbine expansion temperature: $\dfrac{T_{02}}{T_{01}} = r_p^{-(\gamma-1)/\gamma}$, so $T_{02} = T_{01}\, r_p^{-(\gamma-1)/\gamma}$.

Step 1 – list the data: $T_{01} = 1200$ K, $r_p = 5$, $\gamma = 1.4$.

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: $5^{0.2857} = 1.5838$

Step 4 – divide the inlet temperature by that factor: $T_{02} = \dfrac{1200}{1.5838}$

Step 5 – evaluate: $T_{02} = 757.7$ K

Step 6 – round: $T_{02} \approx 758$ K

Final Answer: $T_{02} \approx 758 \text{ K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q46

Answer Key

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