GATE Aerospace Engineering

Sample Paper – 5

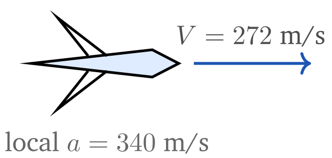
Duration: 128 Minutes **Maximum Marks: 72**

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 272 m/s at an altitude where the local speed of sound is 340 m/s, as indicated below. The flight Mach number is: **[1 mark]**



(A) 0.80

(B) 1.25

(C) 0.74

(D) 0.85

Q2. In the low-speed, incompressible flow of air over a body, the freestream velocity is 100 m/s and, at a point on the surface, the local velocity is 120 m/s. The pressure coefficient $\left(C_p = 1 - (V/V_\infty)^2\right)$ at that point is: **[1 mark]**

(A) $+0.44$

(B) -0.44

(C) -0.20

(D) -1.44

Q3. In a low-speed wind tunnel the dynamic pressure of the working section is 5000 Pa in air of density 1.0 kg/m^3. The corresponding airspeed $\left(q = \frac{1}{2}\rho V^2\right)$ is: **[1 mark]**

(A) 70.7 m/s

(B) 141.4 m/s

(C) 50.0 m/s

(D) 100.0 m/s

Q4. An aircraft flies at 100 m/s in air of density 1.2 kg/m^3. Its wing planform area is 20 m^2 and the drag coefficient is 0.025. The total drag force is: **[1 mark]**

(A) 1500 N

(B) 3000 N

(C) 6000 N

(D) 2400 N

Q5. A wing section of chord 2 m moves through air of density 1.225 kg/m^3 and dynamic viscosity 1.8×10^{-5} Pa·s at a speed of 20 m/s. The Reynolds number based on the chord is nearest to: **[1 mark]**

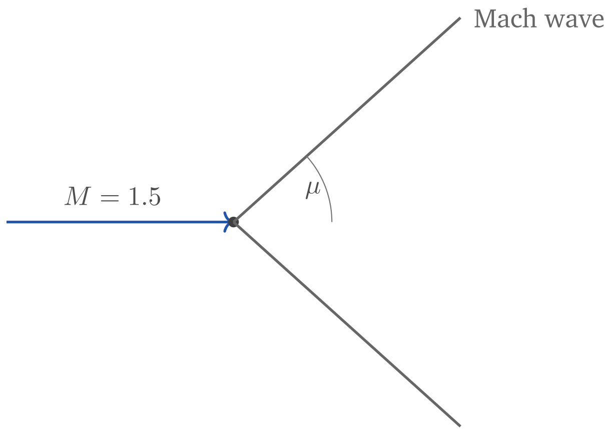
(A) 1.36×10^6

(B) 5.44×10^6

(C) 2.72×10^6

(D) 2.72×10^5

Q6. A slender body moves through still air at a Mach number of 1.5, generating the Mach wave shown. The Mach angle $\left(\mu = \sin^{-1}(1/M)\right)$ is nearest to: **[1 mark]**



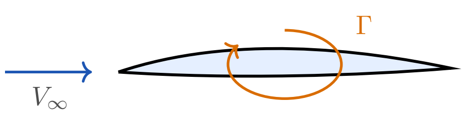
(A) $30.0°$

(B) $19.5°$

(C) $48.6°$

(D) $41.8°$

Q7. A two-dimensional airfoil section in a stream of density 1.225 kg/m^3 and freestream speed 40 m/s develops a bound circulation of $\Gamma = 15$ m^2/s, as shown. By the Kutta–Joukowski theorem $\left(L' = \rho V_\infty \Gamma\right)$, the lift per unit span is nearest to: **[1 mark]**



(A) 490 N/m

(B) 1470 N/m

(C) 735 N/m

(D) 600 N/m

Q8. A laminar boundary layer develops over a flat plate held parallel to the flow. At a station where the Reynolds number based on the distance from the leading edge is 10^6, the local laminar skin-friction coefficient $\left(C_f = 1.328/\sqrt{Re}\right)$ is nearest to: **[1 mark]**

(A) 6.64×10^{-4}

(B) 1.328×10^{-3}

(C) 1.328×10^{-2}

(D) 2.656×10^{-3}

Q9. A turbulent boundary layer grows over a flat plate. At a station $x = 1$ m from the leading edge, where the local Reynolds number is 10^7, the boundary-layer thickness $\left(\delta = 0.37x/Re_x^{0.2}\right)$ is nearest to: **[1 mark]**

(A) 5.0 mm

(B) 7.4 mm

(C) 14.7 mm

(D) 25.1 mm

Q10. At a point in a low-speed airstream ($\rho = 1.225$ kg/m^3) the static pressure is 100,000 Pa and the local velocity is 50 m/s. Treating the flow as incompressible, the total (stagnation) pressure at that point $\left(p_0 = p + \frac{1}{2}\rho V^2\right)$ is: **[1 mark]**

(A) 100,000 Pa

(B) 101,531 Pa

(C) 103,062 Pa

(D) 98,469 Pa

Q11. A wing has a zero-lift drag coefficient of 0.020, an aspect ratio of 8 and an Oswald span-efficiency factor of 0.90. When it operates at a lift coefficient of 0.60, the total drag coefficient $\left(C_D = C_{D,0} + C_L^2/(\pi e\, AR)\right)$ is nearest to: **[1 mark]**

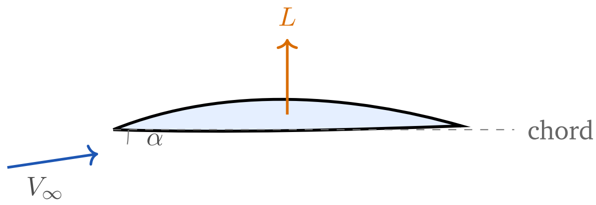
(A) 0.0200

(B) 0.0359

(C) 0.0159

(D) 0.0500

Q12. A thin cambered airfoil has a zero-lift angle of attack of -2° and obeys the thin-airfoil result $c_\ell = 2\pi(\alpha - \alpha_{L0})$, with angles in radians. When set at a geometric angle of attack of $+4^\circ$, as shown, the section lift coefficient is nearest to: **[1 mark]**



(A) 0.439

(B) 0.219

(C) 0.658

(D) 0.878

Flight Mechanics & Space Dynamics

Q13. An aircraft performs a steady, level, co-ordinated turn at a constant bank angle of 45°. The load factor $\left(n = 1/\cos\phi\right)$ acting on the aircraft is: **[1 mark]**

(A) 1.00

(B) 1.414

(C) 2.00

(D) 1.155

Q14. An aircraft of weight $60{,}000$ N cruises in steady, level flight with a lift-to-drag ratio of 15. The thrust required from the engines is: **[1 mark]**

(A) 4000 N

(B) $900{,}000$ N

(C) 9000 N

(D) 6000 N

Q15. An aircraft of weight $30{,}000$ N has a wing area of 20 m^2 and a maximum lift coefficient of 1.6. At sea level ($\rho = 1.225$ kg/m^3), the stalling speed in level flight is nearest to: **[1 mark]**

(A) 27.7 m/s

(B) 55.3 m/s

(C) 39.1 m/s

(D) 45.2 m/s

Q16. For a certain aircraft the neutral point lies at $0.42\,\bar{c}$ and the centre of gravity lies at $0.26\,\bar{c}$ from the leading edge of the mean aerodynamic chord $\bar{c}$. The static margin of the aircraft is: **[1 mark]**

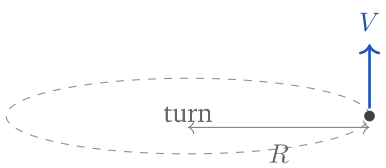
(A) 0.16

(B) 0.26

(C) 0.42

(D) 0.68

Q17. An aircraft flies a steady, level, co-ordinated turn at a true airspeed of 100 m/s and a bank angle of $30°$, as shown. The turn (yaw) rate $\left(\dot{\psi} = g\tan\phi/V\right)$ is nearest to: **[1 mark]**



(A) 0.0566 rad/s

(B) 0.0981 rad/s

(C) 0.0283 rad/s

(D) 0.1132 rad/s

Q18. In aircraft design, a wing set with positive geometric dihedral primarily provides which of the following? **[1 mark]**

(A) Longitudinal (pitch) static stability, by making $dC_m/d\alpha < 0$

(B) An increase in the maximum lift coefficient of the wing

(C) Directional (yaw) static stability, by making $C_{n\beta} > 0$

(D) Lateral (roll) static stability, giving a restoring rolling moment in a sideslip ($C_{l\beta} < 0$)

Q19. An aircraft flies straight and level at a speed of 80 m/s while its total drag is 2000 N. The power required to overcome the drag at this condition is: **[1 mark]**

(A) 80 kW

(B) 160 kW

(C) 320 kW

(D) 200 kW

Q20. An aircraft of weight $40{,}000$ N has a wing planform area of 25 m^2. Its wing loading (weight per unit wing area) is: **[1 mark]**

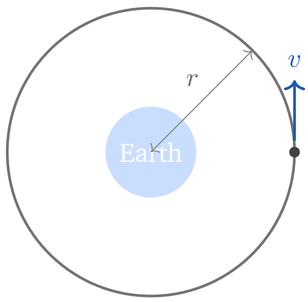
(A) 1600 N/m^2

(B) 800 N/m^2

(C) 2500 N/m^2

(D) 1000 N/m^2

Q21. A satellite moves in a circular orbit of radius 8000 km about the Earth, as sketched. 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) 5062 s

(C) 8460 s

(D) 7122 s

Q22. A satellite is in an elliptic orbit about the Earth with a semi-major axis of 12,000 km. At a point where its distance from the Earth's centre is 8000 km, its speed $\left(v = \sqrt{\mu(\frac{2}{r} - \frac{1}{a})}\right)$ is nearest to: **[2 marks]**

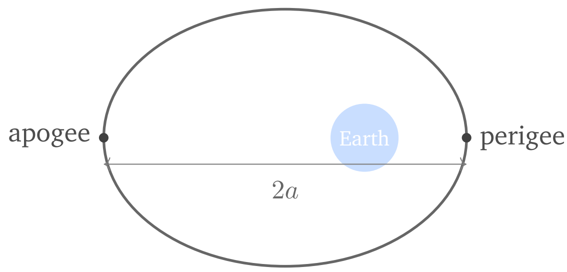
(A) 8.15 km/s

(B) 7.06 km/s

(C) 9.66 km/s

(D) 6.32 km/s

Q23. A satellite is in an elliptic orbit about the Earth with a perigee radius of 8000 km and an apogee radius of 12,000 km, as shown. The eccentricity of the orbit $\left(e = (r_a - r_p)/(r_a + r_p)\right)$ is: **[2 marks]**



(A) 0.333

(B) 0.100

(C) 0.250

(D) 0.200

Aerospace Structures

Q24. A straight aluminium bar is fully restrained between two rigid walls so that it cannot expand, then its temperature is raised by 50 °C. The material has Young's modulus 200 GPa and a coefficient of thermal expansion of 12×10^{-6} /°C. The thermal (compressive) stress induced in the bar $\left(\sigma = E\,\alpha\,\Delta T\right)$ is: **[2 marks]**

(A) 60 MPa

(B) 120 MPa

(C) 240 MPa

(D) 100 MPa

Q25. A beam of solid circular cross-section of diameter 60 mm carries, at a section, a bending moment of 3 kN·m. The maximum bending (flexural) stress at that section $\left(\sigma = 32M/\pi d^3\right)$ is nearest to: **[2 marks]**

(A) 35.4 MPa

(B) 70.7 MPa

(C) 106.1 MPa

(D) 141.5 MPa

Q26. A solid circular shaft of diameter 60 mm transmits a torque of 3 kN·m. The maximum torsional shear stress at the outer surface $\left(\tau = 16T/\pi d^3\right)$ is nearest to: **[2 marks]**

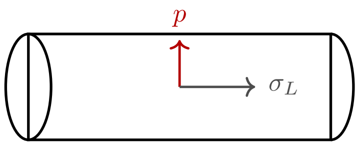
(A) 70.7 MPa

(B) 35.4 MPa

(C) 141.5 MPa

(D) 17.7 MPa

Q27. A thin-walled cylindrical pressure vessel of internal diameter 1.2 m and wall thickness 12 mm carries an internal gauge pressure of 2.5 MPa, as shown. The longitudinal (axial) stress in the wall $\left(\sigma_L = pd/4t\right)$ is: **[2 marks]**



$d = 1.2$ m, $t = 12$ mm

(A) 62.5 MPa

(B) 125.0 MPa

(C) 31.25 MPa

(D) 250.0 MPa

Q28. A straight column with both ends built-in (fixed–fixed) has a length of 2 m, a second moment of area of 2×10^6 mm^4 about the buckling axis and is made of a material with Young's modulus 200 GPa. The Euler critical buckling load $\left(P_{cr} = 4\pi^2 EI/L^2\right)$ is nearest to: **[2 marks]**

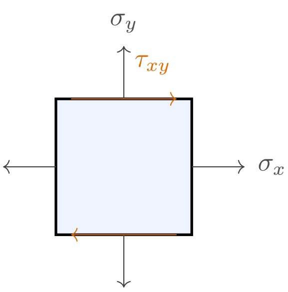
(A) 987 kN

(B) 1974 kN

(C) 494 kN

(D) 3948 kN

Q29. At a point in a loaded structural member the plane-stress components are $\sigma_x = 120$ MPa, $\sigma_y = 40$ MPa and $\tau_{xy} = 40$ MPa, as shown on the stress element. The major principal stress at the point is nearest to: **[2 marks]**



(A) 136.6 MPa

(B) 103.4 MPa

(C) 80.0 MPa

(D) 56.6 MPa

Q30. A cantilever beam of length 1 m carries a concentrated load of 2 kN at its free end. The beam has $E = 200$ GPa and $I = 2 \times 10^6$ mm^4. The strain energy stored in the beam $\left(U = P^2L^3/6EI\right)$ is: **[2 marks]**

(A) 0.833 J

(B) 1.667 J

(C) 3.333 J

(D) 0.556 J

Q31. A single-degree-of-freedom spring–mass system has a stiffness of 2000 N/m and a mass of 8 kg. The undamped natural frequency of the system is nearest to: **[2 marks]**

(A) 1.78 Hz

(B) 2.52 Hz

(C) 15.8 Hz

(D) 5.03 Hz

Q32. A thin-walled single-cell closed tube encloses an area of 0.015 m^2 and carries a torque of 450 N·m. Using the Bredt–Batho theory, the shear flow in the wall $\left(q = T/2A_m\right)$ is: **[2 marks]**

(A) 15.0 kN/m

(B) 30.0 kN/m

(C) 7.5 kN/m

(D) 22.5 kN/m

Q33. A cantilever beam of length 2 m carries a uniformly distributed load of 2 kN/m over its whole span. The beam has $E = 200$ GPa and $I = 4 \times 10^6$ mm^4. The vertical deflection at the free end $\left(\delta = wL^4/8EI\right)$ is: **[2 marks]**

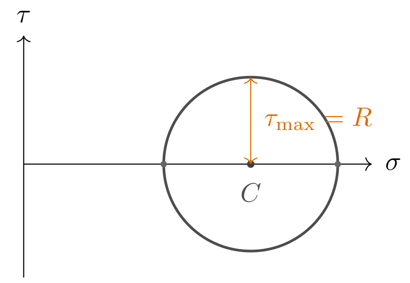
(A) 2.5 mm

(B) 5.0 mm

(C) 10.0 mm

(D) 1.25 mm

Q34. At a point in a thin skin the plane-stress components are $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa and $\tau_{xy} = 45$ MPa. Using the Mohr's-circle construction shown, the maximum in-plane shear stress at the point is nearest to: **[2 marks]**



(A) 30.0 MPa

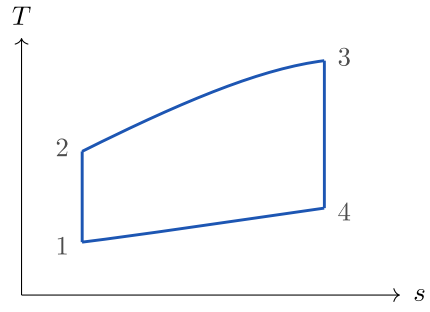
(B) 45.0 MPa

(C) 54.1 MPa

(D) 80.0 MPa

Propulsion

Q35. An ideal (air-standard) Brayton cycle operates with a compressor pressure ratio of 12 and $\gamma = 1.4$, as shown on the T–s diagram. The thermal efficiency of the cycle $\left(\eta = 1 - r_p^{-(\gamma-1)/\gamma}\right)$ is nearest to: **[2 marks]**



(A) 44.8%

(B) 55.2%

(C) 50.8%

(D) 48.2%

Q36. A turbojet ingests air at a mass flow rate of 30 kg/s. The flight (inlet) velocity is 220 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) 7.5 kN

(B) 18.0 kN

(C) 22.8 kN

(D) 11.4 kN

Q37. A jet engine produces a thrust of 15 kN while burning fuel at a rate of 0.6 kg/s. The thrust specific fuel consumption (TSFC) of the engine $\left(\text{TSFC} = \dot{m}_f/F\right)$ is: **[2 marks]**

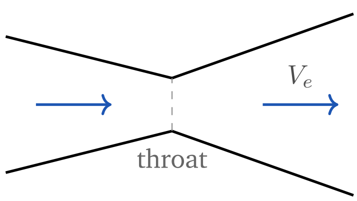
(A) 8×10^{-5} kg/(N · s)

(B) 4×10^{-5} kg/(N · s)

(C) 2×10^{-5} kg/(N · s)

(D) 1.6×10^{-4} kg/(N · s)

Q38. Air expands through the convergent–divergent nozzle shown. From chamber to exit the static temperature drops by 300 K. Taking $c_p = 1005$ J/kg·K and negligible inlet velocity, the exit velocity $\left(V_e = \sqrt{2c_p\,\Delta T}\right)$ is nearest to: **[2 marks]**



(A) 550 m/s

(B) 1100 m/s

(C) 777 m/s

(D) 389 m/s

Q39. Air ($\gamma = 1.4$) is expanded through a nozzle until the flow is just choked at the throat ($M = 1$). The ratio of the static density at the throat to the stagnation density, $\rho^*/\rho_0 = \left(2/(\gamma+1)\right)^{1/(\gamma-1)}$, is nearest to: **[2 marks]**

(A) 0.634

(B) 0.528

(C) 0.833

(D) 0.700

Q40. In an axial-flow compressor stage the mean blade speed is 250 m/s and the whirl (tangential) component of the absolute velocity increases by 160 m/s across the rotor. Using the Euler turbomachinery equation, the specific work input to the air $\left(w = U\,\Delta C_w\right)$ is: **[2 marks]**

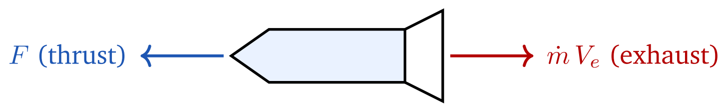
(A) 40 kJ/kg

(B) 25 kJ/kg

(C) 16 kJ/kg

(D) 52.5 kJ/kg

Q41. A rocket engine expels propellant at a mass flow rate of 150 kg/s with an effective exhaust velocity of 3000 m/s, as shown by the thrust free-body. For a perfectly expanded (pressure-matched) nozzle, the thrust produced $\left(F = \dot{m}V_e\right)$ is: **[2 marks]**



(A) 150 kN

(B) 300 kN

(C) 225 kN

(D) 450 kN

Q42. A rocket nozzle produces an effective exhaust velocity of 2500 m/s. Taking $g_0 = 9.81$ m/s^2, the specific impulse of the rocket $\left(I_{sp} = V_e/g_0\right)$ is nearest to: **[2 marks]**

(A) 300 s

(B) 288 s

(C) 255 s

(D) 200 s

Q43. A single-stage rocket has a specific impulse of 280 s (with $g_0 = 9.81$ m/s^2) and an initial-to-final mass ratio of 4. Using the Tsiolkovsky rocket equation, the ideal velocity increment $\Delta v = g_0 I_{sp} \ln(m_0/m_f)$ is nearest to: **[2 marks]**

(A) 2707 m/s

(B) 5493 m/s

(C) 2746 m/s

(D) 3808 m/s

Q44. A gas-turbine combustor burns a hydrocarbon fuel whose stoichiometric air–fuel ratio is 15. In operation the actual air–fuel ratio supplied is 12. The equivalence ratio of the mixture $\left(\phi = (A/F)_{\text{stoich}}/(A/F)_{\text{actual}}\right)$ is: **[2 marks]**

(A) 0.80

(B) 0.75

(C) 1.00

(D) 1.25

Q45. A jet engine flies at 250 m/s and produces an exhaust jet of velocity 550 m/s. Using the ideal (Froude) propulsive efficiency $\left(\eta_p = 2V_0/(V_e + V_0)\right)$, the propulsive efficiency is: **[2 marks]**

(A) 0.50

(B) 0.75

(C) 0.625

(D) 0.833

Q46. Air enters the compressor of a gas-turbine engine at a stagnation temperature of 300 K and is compressed isentropically through a pressure ratio of 5 $(\gamma = 1.4)$. The compressor-exit stagnation temperature $\left(T_{02} = T_{01}\, r_p^{(\gamma-1)/\gamma}\right)$ is nearest to: **[2 marks]**

(A) 300 K

(B) 435 K

(C) 475 K

(D) 543 K

Detailed Solutions

Q1.

Solution

Concept – Mach number: The Mach number is the ratio of the flight speed to the local speed of sound, $M = V/a$.

Step 1 – list the data: $V = 272$ m/s, $a = 340$ m/s.

Step 2 – write the definition: $M = \dfrac{V}{a}$

Step 3 – substitute the numbers: $M = \dfrac{272}{340}$

Step 4 – evaluate: $M = 0.80$

Step 5 – interpret: $M < 1$, so the flow is subsonic.

Final Answer: $M = 0.80 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept – pressure coefficient in incompressible flow: $C_p = 1 - \left(\dfrac{V}{V_\infty}\right)^2$.

Step 1 – list the data: $V_\infty = 100$ m/s, $V = 120$ m/s.

Step 2 – form the velocity ratio: $\dfrac{V}{V_\infty} = \dfrac{120}{100} = 1.20$

Step 3 – square the ratio: $(1.20)^2 = 1.44$

Step 4 – substitute into the formula: $C_p = 1 - 1.44$

Step 5 – evaluate: $C_p = -0.44$

Step 6 – interpret: A negative C_p means the local static pressure is below freestream, consistent with the flow having sped up.

Final Answer: $C_p = -0.44 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q2

Q3.

Solution

Concept – dynamic pressure: $q = \frac{1}{2}\rho V^2$, so $V = \sqrt{2q/\rho}$.

Step 1 – list the data: $q = 5000$ Pa, $\rho = 1.0$ kg/m^3.

Step 2 – rearrange for the velocity: $V = \sqrt{\dfrac{2q}{\rho}}$

Step 3 – form the numerator $2q$**:** $2q = 2 \times 5000 = 10000$

Step 4 – divide by the density: $\dfrac{10000}{1.0} = 10000$

Step 5 – take the square root: $V = \sqrt{10000} = 100$ m/s

Final Answer: $V = 100$ m/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

Q4.

Solution

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

Step 1 – list the data: $\rho = 1.2$ kg/m^3, $V = 100$ m/s, $S = 20$ m^2, $C_D = 0.025$.

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

Step 3 – compute the dynamic pressure: $q = \frac{1}{2}(1.2)(10000)$

$q = 0.6 \times 10000 = 6000$ Pa

Step 4 – multiply by the wing area: $qS = 6000 \times 20 = 120000$ N

Step 5 – multiply by the drag coefficient: $D = 120000 \times 0.025$

$D = 3000$ N

Final Answer: $D = 3000$ N $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – Reynolds number: $Re = \dfrac{\rho V L}{\mu}$.

Step 1 – list the data: $\rho = 1.225$ kg/m^3, $V = 20$ m/s, $L = 2$ m, $\mu = 1.8 \times 10^{-5}$ Pa$\cdot$s.

Step 2 – form the numerator $\rho V L$**:** $1.225 \times 20 = 24.5$

$24.5 \times 2 = 49.0$

Step 3 – divide by the viscosity: $Re = \dfrac{49.0}{1.8 \times 10^{-5}}$

Step 4 – evaluate: $Re = 2.722 \times 10^6$

$Re \approx 2.72 \times 10^6$

Final Answer: $Re \approx 2.72 \times 10^6 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q5

Q6.

Solution

Concept – Mach angle: $\mu = \sin^{-1}\left(\dfrac{1}{M}\right)$.

Step 1 – list the data: $M = 1.5$.

Step 2 – form the ratio $1/M$**:** $\dfrac{1}{M} = \dfrac{1}{1.5} = 0.6667$

Step 3 – take the inverse sine: $\mu = \sin^{-1}(0.6667)$

Step 4 – evaluate: $\mu = 41.8°$

Final Answer: $\mu \approx 41.8° \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

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

Step 1 – list the data: $\rho = 1.225$ kg/m^3, $V_\infty = 40$ m/s, $\Gamma = 15$ m^2/s.

Step 2 – multiply density by velocity: $\rho V_\infty = 1.225 \times 40 = 49.0$

Step 3 – multiply by the circulation: $L' = 49.0 \times 15$

Step 4 – evaluate: $L' = 735$ N/m

Final Answer: $L' = 735$ N/m $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – laminar skin-friction coefficient: $C_f = \dfrac{1.328}{\sqrt{Re}}$ (Blasius flat-plate result).

Step 1 – list the data: $Re = 10^6$.

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

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

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

Final Answer: $C_f = 1.328 \times 10^{-3} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – turbulent boundary-layer thickness: $\delta = \dfrac{0.37\,x}{Re_x^{0.2}}$.

Step 1 – list the data: $x = 1$ m, $Re_x = 10^7$.

Step 2 – raise the Reynolds number to the power 0.2**:** $Re_x^{0.2} = (10^7)^{0.2} = 10^{1.4}$

$10^{1.4} = 25.12$

Step 3 – form the numerator $0.37x$**:** $0.37 \times 1 = 0.37$

Step 4 – divide: $\delta = \dfrac{0.37}{25.12}$

$\delta = 0.01473$ m

Step 5 – convert to millimetres: $\delta = 0.01473 \times 1000 = 14.7$ mm

Final Answer: $\delta \approx 14.7$ mm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – stagnation pressure (incompressible): $p_0 = p + \frac{1}{2}\rho V^2$.

Step 1 – list the data: $p = 100000$ Pa, $\rho = 1.225$ kg/m^3, $V = 50$ m/s.

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

Step 3 – compute the dynamic pressure: $\frac{1}{2}\rho V^2 = 0.6125 \times 2500$

$= 1531.25$ Pa

Step 4 – add to the static pressure: $p_0 = 100000 + 1531.25$

$p_0 = 101531$ Pa

Final Answer: $p_0 \approx 101531$ Pa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – drag polar: $C_D = C_{D,0} + \dfrac{C_L^2}{\pi e\, AR}$.

Step 1 – list the data: $C_{D,0} = 0.020$, $C_L = 0.60$, $e = 0.90$, $AR = 8$.

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

Step 3 – form the denominator $\pi e\, AR$: $\pi \times 0.90 \times 8 = 3.1416 \times 7.2$

$= 22.62$

Step 4 – compute the induced-drag term: $\dfrac{0.36}{22.62} = 0.01592$

Step 5 – add the zero-lift drag: $C_D = 0.020 + 0.01592$

$C_D = 0.0359$

Final Answer: $C_D \approx 0.0359 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q11

Q12.

Solution

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

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

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

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

$= 6 \times 0.017453$

$= 0.10472$ rad

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

$= 6.2832 \times 0.10472$

Step 5 – evaluate: $c_\ell = 0.658$

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

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – load factor in a level turn: Vertical equilibrium in a banked turn gives $L\cos\phi = W$, so $n = L/W = 1/\cos\phi$.

Step 1 – list the data: $\phi = 45°$.

Step 2 – evaluate the cosine: $\cos 45° = 0.7071$

Step 3 – take the reciprocal: $n = \dfrac{1}{0.7071}$

Step 4 – evaluate: $n = 1.414$

Final Answer: $n = 1.414 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – thrust in steady level flight: Level flight needs $L = W$ and $T = D$, and since L/D is given, $T = \dfrac{W}{L/D}$.

Step 1 – list the data: $W = 60000$ N, $L/D = 15$.

Step 2 – set lift equal to weight: $L = W = 60000$ N

Step 3 – divide by the lift-to-drag ratio: $T = \dfrac{60000}{15}$

Step 4 – evaluate: $T = 4000$ N

Final Answer: $T = 4000\ \text{N} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – stalling speed: At the stall $C_L = C_{L,\max}$, so $W = \frac{1}{2}\rho V_s^2 S\, C_{L,\max}$, giving $V_s = \sqrt{\dfrac{2W}{\rho S\, C_{L,\max}}}$.

Step 1 – list the data: $W = 30000$ N, $\rho = 1.225$ kg/m^3, $S = 20$ m^2, $C_{L,\max} = 1.6$.

Step 2 – form the numerator $2W$: $2W = 2 \times 30000 = 60000$

Step 3 – form the denominator $\rho S\,C_{L,\max}$: $1.225 \times 20 = 24.5$

$24.5 \times 1.6 = 39.2$

Step 4 – divide: $\dfrac{60000}{39.2} = 1530.6$

Step 5 – take the square root: $V_s = \sqrt{1530.6} = 39.1$ m/s

Final Answer: $V_s \approx 39.1$ m/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – static margin: $\text{SM} = \dfrac{x_{NP} - x_{CG}}{\bar{c}}$, expressed as a fraction of the mean aerodynamic chord.

Step 1 – list the data: $x_{NP} = 0.42\,\bar{c}$, $x_{CG} = 0.26\,\bar{c}$.

Step 2 – subtract the CG location from the neutral-point location: $\text{SM} = 0.42 - 0.26$

Step 3 – evaluate: $\text{SM} = 0.16$

Step 4 – interpret: The CG lies ahead of the neutral point, so the static margin is positive and the aircraft is longitudinally stable.

Final Answer: $\text{SM} = 0.16 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – turn rate in a level co-ordinated turn: The horizontal component of lift provides the centripetal force; the resulting yaw (turn) rate is $\dot{\psi} = \dfrac{g\tan\phi}{V}$.

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

Step 2 – evaluate the tangent: $\tan 30° = 0.5774$

Step 3 – form the numerator $g\tan\phi$: $9.81 \times 0.5774 = 5.664$

Step 4 – divide by the speed: $\dot{\psi} = \dfrac{5.664}{100}$

Step 5 – evaluate: $\dot{\psi} = 0.0566$ rad/s

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

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – role of wing dihedral: Dihedral is the upward inclination of the wings from the horizontal. Its main aerodynamic effect appears when the aircraft sideslips.

Step 1 – picture a sideslip: If the aircraft slips to one side, the leading (down-going) wing meets the relative wind at a higher effective angle of attack than the trailing wing.

Step 2 – resulting forces: The lower (into-wind) wing generates more lift than the other wing.

Step 3 – resulting moment: This lift difference produces a rolling moment that rolls the aircraft away from the sideslip, tending to level the wings.

Step 4 – identify the stability type: A restoring rolling moment with sideslip is the definition of lateral (roll) static stability, expressed as $C_{l\beta} < 0$.

Step 5 – eliminate the others: Pitch stability comes from the tail and CG position, yaw stability from the fin; dihedral does not raise $C_{L,\max}$.

Final Answer: lateral (roll) static stability, $C_{l\beta} < 0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – power required: The power needed to overcome drag in level flight is $P = DV$.

Step 1 – list the data: $D = 2000$ N, $V = 80$ m/s.

Step 2 – multiply drag by speed: $P = 2000 \times 80$

Step 3 – evaluate: $P = 160000$ W

Step 4 – convert to kilowatts: $P = \dfrac{160000}{1000} = 160$ kW

Final Answer: $P = 160$ kW $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – wing loading: Wing loading is the weight carried per unit of wing planform area, W/S.

Step 1 – list the data: $W = 40000$ N, $S = 25$ m^2.

Step 2 – form the ratio: $\frac{W}{S} = \frac{40000}{25}$

Step 3 – evaluate: $\frac{W}{S} = 1600$ N/m^2

Final Answer: $W/S = 1600$ N/m$^2 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

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

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 – cube the radius: $a^3 = (8 \times 10^6)^3 = 5.12 \times 10^{20}$ m^3

Step 3 – divide by μ: $\frac{a^3}{\mu} = \frac{5.12 \times 10^{20}}{3.986 \times 10^{14}}$

$= 1.2845 \times 10^6$ s^2

Step 4 – take the square root: $\sqrt{1.2845 \times 10^6} = 1133.4$ s

Step 5 – multiply by 2π: $T = 2\pi \times 1133.4$

$T = 6.2832 \times 1133.4$

$T = 7122$ s

Final Answer: $T \approx 7122$ s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q21

Q22.

Solution

Concept – vis-viva equation: $v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$.

Step 1 – list the data: $a = 12000$ km $= 1.2 \times 10^7$ m, $r = 8000$ km $= 8 \times 10^6$ m, $\mu = 3.986 \times 10^{14}$.

Step 2 – evaluate $2/r$: $\dfrac{2}{8 \times 10^6} = 2.5 \times 10^{-7}$

Step 3 – evaluate $1/a$: $\dfrac{1}{1.2 \times 10^7} = 8.333 \times 10^{-8}$

Step 4 – subtract: $2.5 \times 10^{-7} - 8.333 \times 10^{-8} = 1.6667 \times 10^{-7}$

Step 5 – multiply by μ: $3.986 \times 10^{14} \times 1.6667 \times 10^{-7} = 6.6433 \times 10^7$

Step 6 – take the square root: $v = \sqrt{6.6433 \times 10^7} = 8151$ m/s

$v \approx 8.15$ km/s

Final Answer: $v \approx 8.15$ km/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) **Go Back to Q22**

Q23.

Solution

Concept – eccentricity from perigee and apogee radii: $e = \dfrac{r_a - r_p}{r_a + r_p}$.

Step 1 – list the data: $r_p = 8000$ km, $r_a = 12000$ km.

Step 2 – form the numerator: $r_a - r_p = 12000 - 8000 = 4000$ km

Step 3 – form the denominator: $r_a + r_p = 12000 + 8000 = 20000$ km

Step 4 – divide: $e = \dfrac{4000}{20000}$

Step 5 – evaluate: $e = 0.20$

Final Answer: $e = 0.20 \Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q23**

Q24.

Solution

Concept – fully restrained thermal stress: If a bar is prevented from expanding, the suppressed thermal strain $\alpha\,\Delta T$ produces a stress $\sigma = E\,\alpha\,\Delta T$.

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

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

$= 6 \times 10^{-4}$

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

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

$\sigma = 120$ MPa

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

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – bending stress in a circular section: $\sigma = \dfrac{Mc}{I}$ with $c = d/2$ and $I = \dfrac{\pi d^4}{64}$, which reduces to $\sigma = \dfrac{32M}{\pi d^3}$.

Step 1 – list the data: $M = 3$ kN·m $= 3000$ N·m, $d = 60$ mm $= 0.06$ m.

Step 2 – cube the diameter: $d^3 = (0.06)^3 = 2.16 \times 10^{-4}$ m^3

Step 3 – form the denominator πd^3**:** $\pi \times 2.16 \times 10^{-4} = 6.786 \times 10^{-4}$

Step 4 – form the numerator $32M$**:** $32 \times 3000 = 96000$

Step 5 – divide: $\sigma = \dfrac{96000}{6.786 \times 10^{-4}}$

$\sigma = 1.415 \times 10^8$ Pa

$\sigma = 141.5$ MPa

Final Answer: $\sigma \approx 141.5$ MPa $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q25

Q26.

Solution

Concept – torsional shear stress in a solid shaft: $\tau = \dfrac{Tr}{J}$ with $r = d/2$ and $J = \dfrac{\pi d^4}{32}$, which reduces to $\tau = \dfrac{16T}{\pi d^3}$.

Step 1 – list the data: $T = 3$ kN·m $= 3000$ N·m, $d = 60$ mm $= 0.06$ m.

Step 2 – cube the diameter: $d^3 = (0.06)^3 = 2.16 \times 10^{-4}$ m^3

Step 3 – form the denominator πd^3**:** $\pi \times 2.16 \times 10^{-4} = 6.786 \times 10^{-4}$

Step 4 – form the numerator $16T$**:** $16 \times 3000 = 48000$

Step 5 – divide: $\tau = \dfrac{48000}{6.786 \times 10^{-4}}$

$\tau = 7.074 \times 10^7$ Pa

$\tau = 70.7$ MPa

Final Answer: $\tau \approx 70.7$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

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

Step 1 – list the data: $p = 2.5$ MPa $= 2.5 \times 10^6$ Pa, $d = 1.2$ m, $t = 12$ mm $= 0.012$ m.

Step 2 – form the numerator pd**:** $2.5 \times 10^6 \times 1.2 = 3.0 \times 10^6$

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

Step 4 – divide: $\sigma_L = \frac{3.0 \times 10^6}{0.048}$

$\sigma_L = 6.25 \times 10^7$ Pa

$\sigma_L = 62.5$ MPa

Final Answer: $\sigma_L = 62.5$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – Euler buckling of a fixed–fixed column: For both ends built-in the effective length is $L/2$, so $P_{cr} = \frac{\pi^2 EI}{(L/2)^2} = \frac{4\pi^2 EI}{L^2}$.

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 $4\pi^2$**:** $4\pi^2 = 4 \times 9.8696 = 39.478$

$39.478 \times 4 \times 10^5 = 1.5791 \times 10^7$

Step 4 – divide by L^2**:** $L^2 = 2^2 = 4$

$P_{cr} = \frac{1.5791 \times 10^7}{4}$

$P_{cr} = 3.948 \times 10^6$ N

Step 5 – convert to kilonewtons: $P_{cr} = 3948$ kN

Final Answer: $P_{cr} \approx 3948$ kN $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

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

Step 1 – list the data: $\sigma_x = 120$ MPa, $\sigma_y = 40$ MPa, $\tau_{xy} = 40$ MPa.

Step 2 – compute the average normal stress: $\dfrac{\sigma_x + \sigma_y}{2} = \dfrac{120 + 40}{2} = 80$

Step 3 – compute the half-difference: $\dfrac{\sigma_x - \sigma_y}{2} = \dfrac{120 - 40}{2} = 40$

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

$= \sqrt{1600 + 1600}$

$= \sqrt{3200}$

$= 56.57$

Step 5 – add to the average: $\sigma_1 = 80 + 56.57$

$\sigma_1 = 136.6$ MPa

Final Answer: $\sigma_1 \approx 136.6 \text{ MPa} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – bending strain energy of a tip-loaded cantilever: $U = \dfrac{P^2 L^3}{6EI}$.

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

Step 2 – square the load: $P^2 = (2000)^2 = 4 \times 10^6$

Step 3 – cube the length: $L^3 = 1^3 = 1$

Step 4 – form the numerator P^2L^3**:** $4 \times 10^6 \times 1 = 4 \times 10^6$

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

$= 2.4 \times 10^6$

Step 6 – divide: $U = \dfrac{4 \times 10^6}{2.4 \times 10^6}$

$U = 1.667$ J

Final Answer: $U \approx 1.667 \text{ J} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – natural frequency of a spring–mass system: $\omega_n = \sqrt{k/m}$ and $f_n = \omega_n/2\pi$.

Step 1 – list the data: $k = 2000$ N/m, $m = 8$ kg.

Step 2 – form the stiffness-to-mass ratio: $\dfrac{k}{m} = \dfrac{2000}{8} = 250$

Step 3 – take the square root: $\omega_n = \sqrt{250} = 15.81$ rad/s

Step 4 – divide by 2π**:** $f_n = \dfrac{15.81}{6.2832}$

Step 5 – evaluate: $f_n = 2.52$ Hz

Final Answer: $f_n \approx 2.52$ Hz $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – shear flow in a thin closed tube (Bredt–Batho): $q = \dfrac{T}{2A_m}$, where A_m is the area enclosed by the wall mid-line.

Step 1 – list the data: $T = 450$ N·m, $A_m = 0.015$ m^2.

Step 2 – form the denominator $2A_m$**:** $2 \times 0.015 = 0.03$

Step 3 – divide: $q = \dfrac{450}{0.03}$

Step 4 – evaluate: $q = 15000$ N/m

$q = 15.0$ kN/m

Final Answer: $q = 15.0$ kN/m $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – tip deflection of a cantilever under UDL: $\delta = \dfrac{wL^4}{8EI}$.

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

Step 2 – raise the length to the fourth power: $L^4 = 2^4 = 16$

Step 3 – form the numerator wL^4: $2000 \times 16 = 32000$

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

$= 6.4 \times 10^6$

Step 5 – divide: $\delta = \dfrac{32000}{6.4 \times 10^6}$

$\delta = 5 \times 10^{-3}$ m

Step 6 – convert to millimetres: $\delta = 5.0$ mm

Final Answer: $\delta = 5.0$ mm $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – maximum in-plane shear stress: $\tau_{\max} = \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$, the radius of Mohr's circle.

Step 1 – list the data: $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa, $\tau_{xy} = 45$ MPa.

Step 2 – compute the half-difference: $\dfrac{\sigma_x - \sigma_y}{2} = \dfrac{100 - 40}{2} = 30$

Step 3 – square the half-difference: $30^2 = 900$

Step 4 – square the shear stress: $45^2 = 2025$

Step 5 – add the squares: $900 + 2025 = 2925$

Step 6 – take the square root: $\tau_{\max} = \sqrt{2925} = 54.1$ MPa

Final Answer: $\tau_{\max} \approx 54.1$ MPa $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – ideal Brayton-cycle efficiency: $\eta = 1 - r_p^{-(\gamma-1)/\gamma}$.

Step 1 – list the data: $r_p = 12$, $\gamma = 1.4$.

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

Step 3 – raise the pressure ratio to that power: $12^{0.2857} = 2.034$

Step 4 – take the reciprocal: $\frac{1}{2.034} = 0.4917$

Step 5 – subtract from one: $\eta = 1 - 0.4917$

$\eta = 0.508$

$\eta = 50.8\%$

Final Answer: $\eta \approx 50.8\% \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q35

Q36.

Solution

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

Step 1 – list the data: $\dot{m} = 30$ kg/s, $V_0 = 220$ m/s, $V_e = 600$ m/s.

Step 2 – form the velocity difference: $V_e - V_0 = 600 - 220 = 380$ m/s

Step 3 – multiply by the mass flow: $F = 30 \times 380$

Step 4 – evaluate: $F = 11400$ N

$F = 11.4$ kN

Final Answer: $F = 11.4$ kN $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – thrust specific fuel consumption: $\text{TSFC} = \frac{\dot{m}_f}{F}$.

Step 1 – list the data: $\dot{m}_f = 0.6$ kg/s, $F = 15$ kN $= 15000$ N.

Step 2 – form the ratio: $\text{TSFC} = \frac{0.6}{15000}$

Step 3 – evaluate: $\text{TSFC} = 4 \times 10^{-5}\ \text{kg/(N} \cdot \text{s)}$

Final Answer: $\text{TSFC} = 4 \times 10^{-5}\ \text{kg/(N} \cdot \text{s)} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – nozzle exit velocity from an energy balance: 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 · K, $\Delta T = 300$ K.

Step 2 – form the product $2c_p\Delta T$: $2 \times 1005 = 2010$

$2010 \times 300 = 603000$

Step 3 – take the square root: $V_e = \sqrt{603000}$

Step 4 – evaluate: $V_e = 776.5$ m/s

$V_e \approx 777$ m/s

Final Answer: $V_e \approx 777\ \text{m/s} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – critical (choked) density ratio: $\dfrac{\rho^*}{\rho_0} = \left(\dfrac{2}{\gamma+1}\right)^{1/(\gamma-1)}$.

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

Step 2 – evaluate the base $\dfrac{2}{\gamma+1}$: $\dfrac{2}{1.4+1} = \dfrac{2}{2.4} = 0.8333$

Step 3 – evaluate the exponent $\dfrac{1}{\gamma-1}$: $\dfrac{1}{0.4} = 2.5$

Step 4 – raise the base to the exponent: $0.8333^{2.5} = 0.634$

Final Answer: $\rho^*/\rho_0 \approx 0.634 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – Euler work of a compressor stage: For purely axial inlet swirl assumption, $w = U\,\Delta C_w$, the product of blade speed and the change in whirl velocity.

Step 1 – list the data: $U = 250$ m/s, $\Delta C_w = 160$ m/s.

Step 2 – multiply: $w = 250 \times 160$

Step 3 – evaluate: $w = 40000$ J/kg

Step 4 – convert to kilojoules: $w = 40$ kJ/kg

Final Answer: $w = 40$ kJ/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – rocket thrust (pressure-matched nozzle): $F = \dot{m}V_e$, the momentum thrust, when the exit pressure equals ambient.

Step 1 – list the data: $\dot{m} = 150$ kg/s, $V_e = 3000$ m/s.

Step 2 – multiply: $F = 150 \times 3000$

Step 3 – evaluate: $F = 450000$ N

$F = 450$ kN

Final Answer: $F = 450$ kN $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q41

Q42.

Solution

Concept – specific impulse: $I_{sp} = \dfrac{V_e}{g_0}$.

Step 1 – list the data: $V_e = 2500$ m/s, $g_0 = 9.81$ m/s^2.

Step 2 – form the ratio: $I_{sp} = \dfrac{2500}{9.81}$

Step 3 – evaluate: $I_{sp} = 254.8$ s

$I_{sp} \approx 255$ s

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

Answer: (C) Go Back to Q42

Q43.

Solution

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

Step 1 – list the data: $I_{sp} = 280$ s, $g_0 = 9.81$ m/s^2, $m_0/m_f = 4$.

Step 2 – form the effective exhaust velocity $g_0 I_{sp}$: $9.81 \times 280 = 2746.8$ m/s

Step 3 – take the natural log of the mass ratio: $\ln 4 = 1.3863$

Step 4 – multiply: $\Delta v = 2746.8 \times 1.3863$

Step 5 – evaluate: $\Delta v = 3808$ m/s

Final Answer: $\Delta v \approx 3808$ m/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q43

Q44.

Solution

Concept – equivalence ratio: $\phi = \frac{(A/F)_{\text{stoich}}}{(A/F)_{\text{actual}}}$; $\phi > 1$ is a rich (fuel-excess) mixture.

Step 1 – list the data: $(A/F)_{\text{stoich}} = 15$, $(A/F)_{\text{actual}} = 12$.

Step 2 – form the ratio: $\phi = \frac{15}{12}$

Step 3 – evaluate: $\phi = 1.25$

Step 4 – interpret: Since $\phi > 1$, less air is supplied than needed for complete combustion, so the mixture is rich.

Final Answer: $\phi = 1.25 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – ideal (Froude) propulsive efficiency: $\eta_p = \frac{2V_0}{V_e + V_0}$.

Step 1 – list the data: $V_0 = 250$ m/s, $V_e = 550$ m/s.

Step 2 – form the numerator $2V_0$: $2 \times 250 = 500$

Step 3 – form the denominator $V_e + V_0$: $550 + 250 = 800$

Step 4 – divide: $\eta_p = \frac{500}{800}$

Step 5 – evaluate: $\eta_p = 0.625$

Final Answer: $\eta_p = 0.625 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – isentropic compression temperature ratio: $\dfrac{T_{02}}{T_{01}} = r_p^{(\gamma-1)/\gamma}$.

Step 1 – list the data: $T_{01} = 300$ K, $r_p = 5$, $\gamma = 1.4$.

Step 2 – evaluate 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 – multiply by the inlet temperature: $T_{02} = 300 \times 1.5838$

Step 5 – evaluate: $T_{02} = 475.1$ K

$T_{02} \approx 475$ K

Final Answer: $T_{02} \approx 475 \text{ K} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q46

Answer Key

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