GATE Aerospace Engineering

Sample Paper – 3

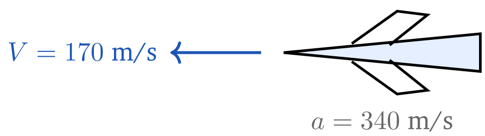
Duration: 128 Minutes **Maximum Marks: 72**

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 $\cdot$ 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 through air in which the local speed of sound is 340 m/s, as sketched. The flight Mach number is: **[1 mark]**



(A) 0.5

(B) 2.0

(C) 0.34

(D) 1.0

Q2. In the low-speed incompressible flow of air over a body, the freestream velocity is 40 m/s and, at a point on the surface, the local velocity is 60 m/s. The pressure coefficient $C_p = 1 - (V/V_\infty)^2$ at that point is: **[1 mark]**

(A) -0.44

(B) $+1.25$

(C) -1.25

(D) -2.25

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, $p_0/p = \left(1 + \frac{\gamma-1}{2}M^2\right)^{\gamma/(\gamma-1)}$, is nearest to: **[1 mark]**

(A) 1.128

(B) 1.276

(C) 1.456

(D) 1.524

Q4. An aircraft flying at 100 m/s at sea level ($\rho = 1.225$ kg/m^3) has a wing area of 20 m^2 and a drag coefficient of 0.02. The total drag force on the wing is: **[1 mark]**

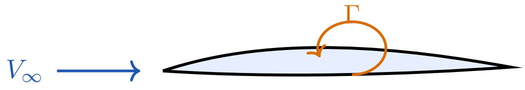
(A) 2450 N

(B) 1225 N

(C) 4900 N

(D) 3675 N

Q5. A two-dimensional airfoil section develops a circulation of $\Gamma = 20$ m^2/s in a stream of air ($\rho = 1.225$ kg/m^3) moving at 50 m/s, as indicated. By the Kutta–Joukowski theorem the lift per unit span is: **[1 mark]**



(A) 2450 N/m

(B) 612.5 N/m

(C) 1225 N/m

(D) 24.5 N/m

Q6. At low speed an airfoil section has a lift coefficient of 0.40. Using the Prandtl–Glauert compressibility correction $c_\ell = c_{\ell,0}/\sqrt{1 - M_\infty^2}$, the section lift coefficient at a freestream Mach number of 0.6 is: **[1 mark]**

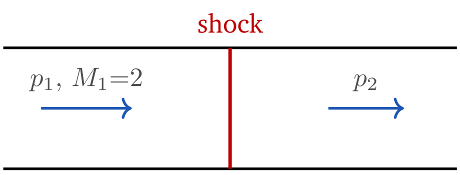
(A) 0.40

(B) 0.32

(C) 0.50

(D) 0.64

Q7. 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

Q8. An elliptical finite wing has an aspect ratio of 8 and a two-dimensional (section) lift-curve slope of $a_0 = 2\pi$ per radian. Using $a = \dfrac{a_0}{1 + a_0/(\pi\, AR)}$

with span efficiency unity, the finite-wing lift-curve slope is nearest to: **[1 mark]**

(A) 6.28 per rad

(B) 5.03 per rad

(C) 4.19 per rad

(D) 3.14 per rad

Q9. A flat plate is held parallel to a stream in which the Reynolds number based on plate length is 10^6. For laminar flow the total (both-side-averaged, one-side) skin-friction drag coefficient is $C_f = 1.328/\sqrt{Re_L}$. Its value here is: **[1 mark]**

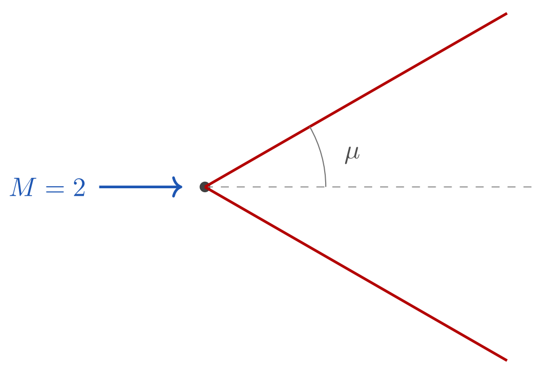
(A) 5.0×10^{-3}

(B) 1.328×10^{-3}

(C) 6.64×10^{-4}

(D) 1.328×10^{-6}

Q10. A body moves through air at a Mach number of 2.0, generating the Mach wave shown. The Mach angle $\mu = \sin^{-1}(1/M)$ is: **[1 mark]**



(A) $60°$

(B) $45°$

(C) $30°$

(D) $90°$

Q11. At a point in a compressible airstream the static pressure is 100 kPa and the local Mach number is 0.8. Using $q = \frac{\gamma}{2} p M^2$ (with $\gamma = 1.4$), the dynamic pressure is: **[1 mark]**

(A) 64.0 kPa

(B) 44.8 kPa

(C) 32.0 kPa

(D) 56.0 kPa

Q12. For a thin airfoil the lift-curve slope is $c_\ell = 2\pi\alpha$ with α in radians. Expressed on a per-degree basis, the lift-curve slope $dc_\ell/d\alpha$ is nearest to: **[1 mark]**

(A) 6.28 per degree

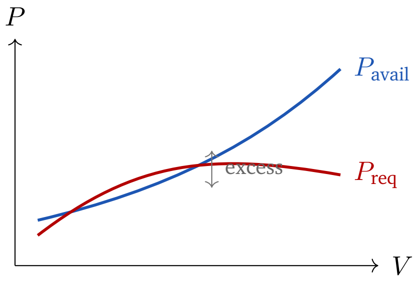
(B) 0.017 per degree

(C) 0.11 per degree

(D) 0.20 per degree

Flight Mechanics & Space Dynamics

Q13. An aircraft of weight 20,000 N climbs steadily. At its climb condition the engine delivers 200 kW of power in excess of that required for level flight, as shown on the power diagram. The steady rate of climb $\left(R/C = P_{\text{excess}}/W\right)$ is: **[1 mark]**



(A) 20 m/s

(B) 10 m/s

(C) 5 m/s

(D) 4 m/s

Q14. An aircraft of weight 20,000 N climbs at a steady speed. The engine thrust is 6000 N and the drag is 4000 N. The climb (flight-path) angle above the horizontal $\left(\sin\gamma = (T-D)/W\right)$ is nearest to: **[1 mark]**

(A) $5.74°$

(B) $11.5°$

(C) $2.87°$

(D) $8.63°$

Q15. An aircraft flies a steady, level, co-ordinated turn at a true airspeed of 100 m/s and a bank angle of $45°$. The radius of the turn $\left(R = V^2/(g\tan\phi)\right)$ is nearest to: **[1 mark]**

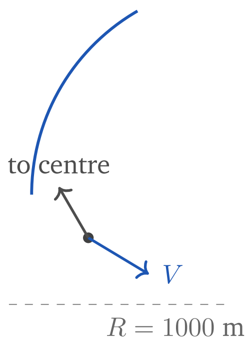
(A) 1019 m

(B) 2039 m

(C) 720 m

(D) 510 m

Q16. An aircraft flies through the bottom of a vertical pull-up at a speed of 100 m/s along a circular arc of radius 1000 m, as shown. The load factor $\left(n = 1 + V^2/(gR)\right)$ experienced is nearest to: **[1 mark]**



(A) 1.00

(B) 1.02

(C) 3.04

(D) 2.02

Q17. A glider descends in a steady, unpowered glide at a forward speed of 60 m/s with a lift-to-drag ratio of 15. The rate of descent (sink rate) $\left(V_v = V/(L/D)\right)$ is: **[1 mark]**

(A) 4 m/s

(B) 15 m/s

(C) 0.9 m/s

(D) 60 m/s

Q18. For an airplane to possess directional (weathercock) static stability about its yaw axis, the yawing-moment characteristic with sideslip angle β must satisfy: **[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 has a $1g$ level-flight stalling speed of 50 m/s. In a steady turn it pulls a load factor of $n = 2$. The stalling speed in the turn $\left(V_{s,\text{turn}} = V_s\sqrt{n}\right)$ is nearest to: **[1 mark]**

(A) 50 m/s

(B) 35.4 m/s

(C) 100 m/s

(D) 70.7 m/s

Q20. An aircraft of weight 50,000 N cruises in steady, level flight at 100 m/s with a lift-to-drag ratio of 10. The power required to overcome drag $\left(P = DV\right)$ is: **[1 mark]**

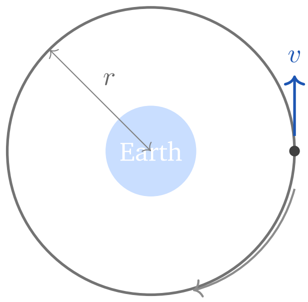
(A) 5000 kW

(B) 50 kW

(C) 100 kW

(D) 500 kW

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



(A) 3600 s

(B) 7200 s

(C) 5829 s

(D) 8640 s

Q22. A satellite moves in a circular orbit of radius 7000 km about the Earth ($\mu = 3.986 \times 10^{14}$ m^3/s^2). The specific orbital energy $\left(\varepsilon = -\mu/2a\right)$ of the orbit is nearest to: **[2 marks]**

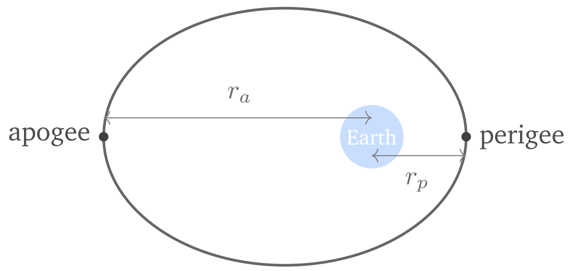
(A) -28.5 MJ/kg

(B) -57.0 MJ/kg

(C) -14.2 MJ/kg

(D) $+28.5$ MJ/kg

Q23. A satellite is in an elliptic orbit about 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) 0.25

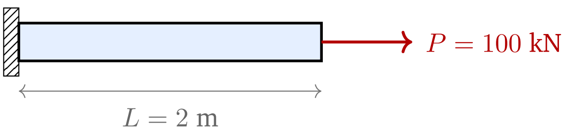
(B) 0.125

(C) 0.0625

(D) 0.20

Aerospace Structures

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



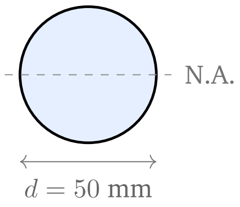
(A) 1 mm

(B) 2 mm

(C) 4 mm

(D) 0.5 mm

Q25. A beam of solid circular cross-section of diameter 50 mm carries a bending moment of 2 kN·m at a section. The maximum bending stress $(\sigma = 32M/\pi d^3)$ is nearest to: **[2 marks]**



(A) 40.7 MPa

(B) 81.5 MPa

(C) 122 MPa

(D) 163 MPa

Q26. A solid circular shaft of diameter 40 mm and length 1 m is made of a material with shear modulus 80 GPa. It 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) 0.025°

Q27. A thin-walled spherical pressure vessel of internal diameter 1 m and wall thickness 5 mm carries an internal gauge pressure of 2 MPa. The membrane (wall) stress $\left(\sigma = pd/4t\right)$ is: **[2 marks]**

(A) 200 MPa

(B) 100 MPa

(C) 50 MPa

(D) 400 MPa

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

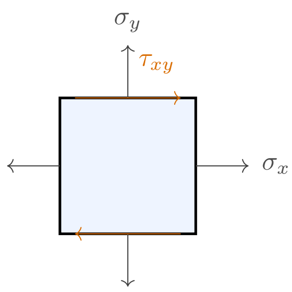
(A) 987 kN

(B) 3948 kN

(C) 1974 kN

(D) 247 kN

Q29. At a point in a loaded member the plane-stress components are $\sigma_x = 90$ MPa, $\sigma_y = 30$ MPa and $\tau_{xy} = 40$ MPa, as shown. The minor (minimum) in-plane principal stress at the point is nearest to: **[2 marks]**



(A) 60 MPa

(B) 10 MPa

(C) 110 MPa

(D) 50 MPa

Q30. A solid circular shaft of diameter 50 mm and length 2 m is made of a material with shear modulus 80 GPa and carries a static torque of 1 kN·m. The strain energy stored $\left(U = T^2L/2GJ,\ J = \pi d^4/32\right)$ is nearest to: **[2 marks]**

(A) 40.7 J

(B) 10.2 J

(C) 5.1 J

(D) 20.4 J

Q31. A single-degree-of-freedom spring–mass system has a stiffness of 5000 N/m and a mass of 5 kg. The undamped natural angular frequency $\left(\omega_n = \sqrt{k/m}\right)$ is: **[2 marks]**

(A) 63.2 rad/s

(B) 31.6 rad/s

(C) 5.03 rad/s

(D) 1000 rad/s

Q32. A single-cell thin-walled closed tube encloses an area of 0.02 m^2 and carries a torque of 800 N·m. Using the Bredt–Batho theory, the shear flow in the wall $\left(q = T/2A_m\right)$ is: **[2 marks]**

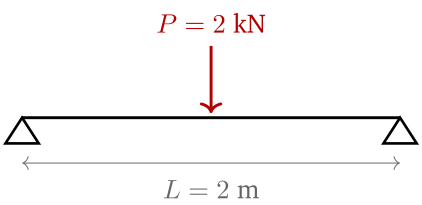
(A) 40 kN/m

(B) 80 kN/m

(C) 20 kN/m

(D) 10 kN/m

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



(A) 0.833 mm

(B) 3.33 mm

(C) 1.67 mm

(D) 0.417 mm

Q34. At a point in a thin skin the plane-stress components are $\sigma_x = 80$ MPa, $\sigma_y = 20$ MPa and $\tau_{xy} = 30$ MPa. The orientation of the principal plane $\left(\tan 2\theta_p = 2\tau_{xy}/(\sigma_x - \sigma_y)\right)$, measured from the x-axis, is nearest to: **[2 marks]**

(A) $45°$

(B) $30°$

(C) $22.5°$

(D) $11.25°$

Propulsion

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

(A) 60.0%

(B) 48.2%

(C) 51.8%

(D) 37.5%

Q36. A turbojet operates with an inlet (flight) velocity of 250 m/s and an exhaust jet velocity of 650 m/s. Neglecting the fuel mass flow and pressure-thrust terms, the specific thrust $\left(F/\dot{m} = V_e - V_0\right)$ is: **[2 marks]**

(A) 400 N·s/kg

(B) 900 N·s/kg

(C) 250 N·s/kg

(D) 650 N·s/kg

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

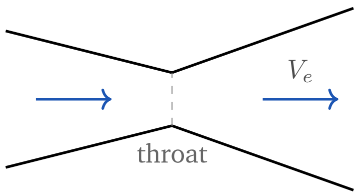
(A) 201 kJ/kg

(B) 1206 kJ/kg

(C) 302 kJ/kg

(D) 603 kJ/kg

Q38. Air expands through the convergent–divergent nozzle shown from a chamber to the exit, with a static-temperature drop of 300 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) 776 m/s

(B) 549 m/s

(C) 1553 m/s

(D) 388 m/s

Q39. Air ($\gamma = 1.4$) is accelerated in 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 $\left(T^*/T_0 = 2/(\gamma+1)\right)$ is: **[2 marks]**

(A) 0.833

(B) 0.528

(C) 0.634

(D) 1.20

Q40. Air flows at 15 kg/s through the compressor of a gas-turbine engine, in which the stagnation temperature rises by 200 K. Taking $c_p = 1005$ J/kg · K, the compressor power $\left(P = \dot{m}\, c_p\, \Delta T_0\right)$ is nearest to: **[2 marks]**

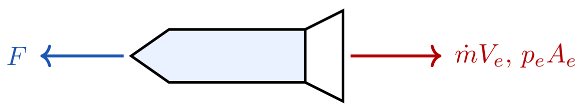
(A) 30.2 MW

(B) 1.51 MW

(C) 0.30 MW

(D) 3.02 MW

Q41. A rocket engine has a propellant mass flow of 100 kg/s and an exhaust velocity of 2800 m/s. The nozzle exit area is 0.5 m^2, the exit pressure is 100 kPa and the ambient pressure is 50 kPa, as shown. The thrust $\left(F = \dot{m}V_e + (p_e - p_a)A_e\right)$ is: **[2 marks]**



(A) 280 kN

(B) 25 kN

(C) 305 kN

(D) 255 kN

Q42. A rocket engine has a specific impulse of 250 s. Taking $g_0 = 9.81$ m/s^2, the effective exhaust velocity $\left(V_e = I_{sp}\, g_0\right)$ is nearest to: **[2 marks]**

(A) 250 m/s

(B) 2452 m/s

(C) 25.5 m/s

(D) 2943 m/s

Q43. A single-stage rocket has a specific impulse of 250 s ($g_0 = 9.81$ m/s^2) and must achieve an ideal velocity increment of 4905 m/s. Using the Tsiolkovsky rocket equation, the required initial-to-final mass ratio $\left(m_0/m_f = e^{\Delta v/(I_{sp} g_0)}\right)$ is nearest to: **[2 marks]**

(A) 2.0

(B) 7.39

(C) 20.1

(D) 3.0

Q44. A gas-turbine combustor is supplied with air at 50 kg/s and burns fuel at 1 kg/s. The fuel–air ratio $\left(f = \dot{m}_f/\dot{m}_a\right)$ of the mixture is: **[2 marks]**

(A) 50

(B) 0.05

(C) 0.02

(D) 0.5

Q45. A jet engine flies at 250 m/s and produces a net thrust of 20 kN. The thrust (propulsive) power delivered $\left(P = F\, V_0\right)$ is: **[2 marks]**

(A) 10 MW

(B) 4 MW

(C) 5 MW

(D) 2.5 MW

Q46. The turbine of a gas-turbine engine receives gas at a stagnation temperature of 1200 K and expands it isentropically through a 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) 1200 K

(B) 2174 K

(C) 960 K

(D) 662 K

Detailed Solutions

Q1.

Solution

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

Step 1 – list the data: $V = 170$ m/s, $a = 340$ m/s.

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

Step 3 – substitute the numbers: $M = \dfrac{170}{340}$

Step 4 – evaluate: $M = 0.5$

Step 5 – interpret: Since $M < 1$, the flight is subsonic.

Final Answer: $M = 0.5 \Rightarrow \boxed{\text{A}}$

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: $V_\infty = 40$ m/s, $V = 60$ m/s.

Step 2 – form the velocity ratio: $\dfrac{V}{V_\infty} = \dfrac{60}{40} = 1.5$

Step 3 – square the ratio: $(1.5)^2 = 2.25$

Step 4 – substitute into the formula: $C_p = 1 - 2.25$

Step 5 – evaluate: $C_p = -1.25$

Step 6 – interpret: A negative C_p means the local pressure is below the freestream static pressure, as expected where the flow speeds up.

Final Answer: $C_p = -1.25 \Rightarrow \boxed{\text{C}}$

Answer: (C) 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 – find the exponent: $\frac{\gamma}{\gamma-1} = \frac{1.4}{0.4} = 3.5$

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

Step 7 – evaluate: $(1.128)^{3.5} = 1.524$

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

Answer: (D) Go Back to Q3

Q4.

Solution

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

Step 1 – list the data: $\rho = 1.225\ \text{kg/m}^3$, $V = 100\ \text{m/s}$, $S = 20\ \text{m}^2$, $C_D = 0.02$.

Step 2 – compute the dynamic pressure: $q = \frac{1}{2}\rho V^2 = \frac{1}{2}(1.225)(100^2)$

$q = 0.6125 \times 10000$

$q = 6125\ \text{Pa}$

Step 3 – multiply by the wing area: $q\, S = 6125 \times 20 = 122500\ \text{N}$

Step 4 – multiply by the drag coefficient: $D = 122500 \times 0.02$

Step 5 – evaluate: $D = 2450\ \text{N}$

Final Answer: $D = 2450\ \text{N} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

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

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

Step 2 – form the product ρV_∞: $1.225 \times 50 = 61.25$

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

Step 4 – evaluate: $L' = 1225$ N/m

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

Answer: (C) Go Back to Q5

Q6.

Solution

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

Step 1 – list the data: $c_{\ell,0} = 0.40$, $M_\infty = 0.6$.

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: $c_\ell = \dfrac{0.40}{0.8}$

Step 6 – evaluate: $c_\ell = 0.50$

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

Answer: (C) Go Back to Q6

Q7.

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: $1.1667 \times 3 = 3.5$

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

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

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – finite-wing lift-curve slope: $a = \dfrac{a_0}{1 + a_0/(\pi\, AR)}$ for an elliptical wing (span efficiency unity).

Step 1 – list the data: $a_0 = 2\pi = 6.2832$ per rad, $AR = 8$.

Step 2 – form $\pi\, AR$**:** $\pi \times 8 = 25.133$

Step 3 – form $a_0/(\pi\, AR)$**:** $\dfrac{6.2832}{25.133} = 0.25$

Step 4 – form the denominator: $1 + 0.25 = 1.25$

Step 5 – divide: $a = \dfrac{6.2832}{1.25}$

Step 6 – evaluate: $a = 5.027 \approx 5.03$ per rad

Final Answer: $a \approx 5.03$ per rad $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

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

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: $C_f = 1.328 \times 10^{-3}$

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

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – Mach angle: The Mach wave makes an angle $\mu = \sin^{-1}(1/M)$ with the flow direction.

Step 1 – list the data: $M = 2.0$.

Step 2 – form $1/M$**:** $\frac{1}{M} = \frac{1}{2} = 0.5$

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 Q10

Q11.

Solution

Concept – dynamic pressure from static pressure and Mach number: $q = \frac{1}{2}\rho V^2$ can be written as $q = \frac{\gamma}{2}\, p\, M^2$ (using $a^2 = \gamma p/\rho$ and $M = V/a$).

Step 1 – list the data: $p = 100$ kPa $= 100000$ Pa, $M = 0.8$, $\gamma = 1.4$.

Step 2 – form $\frac{\gamma}{2}$**:** $\frac{1.4}{2} = 0.7$

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

Step 4 – multiply the terms: $q = 0.7 \times 100000 \times 0.64$

Step 5 – evaluate step by step: $0.7 \times 100000 = 70000$

$70000 \times 0.64 = 44800$ Pa

Step 6 – convert to kilopascals: $q = 44.8$ kPa

Final Answer: $q = 44.8$ kPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q11

Q12.

Solution

Concept – thin-airfoil lift-curve slope per degree: $\frac{dc_\ell}{d\alpha} = 2\pi$ per radian; converting to per degree multiplies by $\pi/180$.

Step 1 – state the slope in radians: $\frac{dc_\ell}{d\alpha} = 2\pi = 6.2832$ per rad

Step 2 – write the conversion factor: $1^\circ = \dfrac{\pi}{180}$ rad $= 0.017453$ rad

Step 3 – multiply the slope by the conversion factor: $\dfrac{dc_\ell}{d\alpha} = 6.2832 \times 0.017453$

Step 4 – evaluate: $\dfrac{dc_\ell}{d\alpha} = 0.1097 \approx 0.11$ per degree

Final Answer: $dc_\ell/d\alpha \approx 0.11$ per degree $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – rate of climb from excess power: $R/C = \dfrac{P_{\text{avail}} - P_{\text{req}}}{W} = \dfrac{P_{\text{excess}}}{W}$.

Step 1 – list the data: $P_{\text{excess}} = 200$ kW $= 200000$ W, $W = 20000$ N.

Step 2 – write the expression: $R/C = \dfrac{P_{\text{excess}}}{W}$

Step 3 – substitute the numbers: $R/C = \dfrac{200000}{20000}$

Step 4 – evaluate: $R/C = 10$ m/s

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

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – climb angle from the thrust equation: Along the flight path, $T = D + W\sin\gamma$, so $\sin\gamma = \dfrac{T-D}{W}$.

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

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

Step 3 – divide by the weight: $\sin\gamma = \dfrac{2000}{20000} = 0.1$

Step 4 – take the inverse sine: $\gamma = \sin^{-1}(0.1)$

Step 5 – evaluate: $\gamma = 5.74^\circ$

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

Answer: (A) Go Back to Q14

Q15.

Solution

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

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

Step 2 – evaluate $\tan\phi$: $\tan 45° = 1$

Step 3 – square the speed: $V^2 = 100^2 = 10000$

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

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

Step 6 – evaluate: $R = 1019.4 \approx 1019$ m

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

Answer: (A) Go Back to Q15

Q16.

Solution

Concept – load factor in a vertical pull-up: At the bottom of a pull-up the lift supports the weight and provides 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 speed: $V^2 = 100^2 = 10000$

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

Step 4 – form the ratio $V^2/(gR)$: $\dfrac{10000}{9810} = 1.0194$

Step 5 – add 1: $n = 1 + 1.0194 = 2.0194$

Step 6 – round: $n \approx 2.02$

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

Answer: (D) Go Back to Q16

Q17.

Solution

Concept – sink rate in a steady glide: The rate of descent is $V_v = \dfrac{V}{L/D}$, since the glide angle satisfies $\tan\gamma = 1/(L/D)$ and $V_v = V \sin\gamma \approx V \tan\gamma$ for shallow glides.

Step 1 – list the data: $V = 60$ m/s, $L/D = 15$.

Step 2 – write the expression: $V_v = \dfrac{V}{L/D}$

Step 3 – substitute the numbers: $V_v = \dfrac{60}{15}$

Step 4 – evaluate: $V_v = 4$ m/s

Final Answer: $V_v = 4 \text{ m/s} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – directional (weathercock) static stability: If the aircraft is disturbed to a positive sideslip β, a stable aircraft must generate a yawing moment that turns the nose back into the wind, i.e. a positive restoring C_n. This requires $\dfrac{dC_n}{d\beta} > 0$.

Step 1 – recall the sign convention: Positive β is nose-left relative to the relative wind; positive C_n yaws the nose to the right, back towards zero sideslip.

Step 2 – state the stability requirement: A restoring moment needs C_n to increase with β, so $\dfrac{dC_n}{d\beta} > 0$.

Step 3 – eliminate the others: $dC_n/d\beta < 0$ is destabilising; $= 0$ is neutral; $dC_l/d\beta$ governs *lateral* (roll) behaviour, not directional.

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

Answer: (A) Go Back to Q18

Q19.

Solution

Concept – stalling speed at increased load factor: At stall $L = nW = \frac{1}{2}\rho V^2 S\, C_{L,\max}$, so the stall speed scales as $V_{s,\text{turn}} = V_s\sqrt{n}$.

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

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

Step 3 – multiply by the level stall speed: $V_{s,\text{turn}} = 50 \times 1.4142$

Step 4 – evaluate: $V_{s,\text{turn}} = 70.7$ m/s

Final Answer: $V_{s,\text{turn}} \approx 70.7 \text{ m/s} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – power required in level flight: $P = D\,V$, and in level flight $D = \dfrac{W}{L/D}$.

Step 1 – list the data: $W = 50000$ N, $V = 100$ m/s, $L/D = 10$.

Step 2 – find the drag: $D = \dfrac{W}{L/D} = \dfrac{50000}{10} = 5000$ N

Step 3 – multiply drag by speed: $P = D\,V = 5000 \times 100$

Step 4 – evaluate: $P = 500000$ W

Step 5 – convert to kilowatts: $P = 500$ kW

Final Answer: $P = 500$ kW $\Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q20**

Q21.

Solution

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

Step 1 – list the data: $r = 7000$ 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: $\dfrac{a^3}{\mu} = \dfrac{3.43 \times 10^{20}}{3.986 \times 10^{14}} = 8.605 \times 10^5$ s^2

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

Step 5 – multiply by 2π: $T = 2\pi \times 927.6 = 6.2832 \times 927.6$

Step 6 – evaluate: $T = 5829$ s ≈ 97.1 min

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

Answer: (C) **Go Back to Q21**

Q22.

Solution

Concept – specific orbital energy: $\varepsilon = -\dfrac{\mu}{2a}$, with $a = r$ for a circular orbit.

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

Step 2 – form the denominator $2a$: $2a = 2 \times 7 \times 10^6 = 1.4 \times 10^7$ m

Step 3 – divide μ by $2a$: $\frac{\mu}{2a} = \frac{3.986 \times 10^{14}}{1.4 \times 10^{7}}$

Step 4 – evaluate: $\frac{\mu}{2a} = 2.847 \times 10^{7}$ J/kg

Step 5 – apply the negative sign: $\varepsilon = -2.847 \times 10^{7}$ J/kg $= -28.5$ MJ/kg

Final Answer: $\varepsilon \approx -28.5$ MJ/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q22

Q23.

Solution

Concept – eccentricity from apsidal radii: $e = \frac{r_a - r_p}{r_a + r_p}$.

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: $e = 0.125 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q23

Q24.

Solution

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

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

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

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

$AE = 1 \times 10^{8}$ N

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

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

Step 6 – convert to millimetres: $\delta = 2$ mm

Final Answer: $\delta = 2$ 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 in SI units: $M = 2$ 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: $\pi \times 1.25 \times 10^{-4} = 3.927 \times 10^{-4}$

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

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 $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q25

Q26.

Solution

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

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

Step 2 – compute the polar second moment J: $d^4 = 0.04^4 = 2.56 \times 10^{-6}$ m^4

$$J = \frac{\pi \times 2.56 \times 10^{-6}}{32} = 2.513 \times 10^{-7} \text{ m}^4$$

Step 3 – form the product GJ: $GJ = 80 \times 10^9 \times 2.513 \times 10^{-7} = 20106 \text{ N} \cdot \text{m}^2$

Step 4 – form the numerator TL: $TL = 500 \times 1 = 500$ N·m^2

Step 5 – divide to get θ in radians: $\theta = \dfrac{500}{20106} = 0.02487$ rad

Step 6 – convert to degrees: $\theta = 0.02487 \times \dfrac{180}{\pi} = 1.42°$

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

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – membrane stress in a thin spherical vessel: For a sphere the wall stress is equal in all directions, $\sigma = \dfrac{pd}{4t}$.

Step 1 – list the data: $p = 2$ MPa $= 2 \times 10^6$ Pa, $d = 1$ m, $t = 5$ mm $= 0.005$ m.

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

Step 3 – form the denominator $4t$**:** $4t = 4 \times 0.005 = 0.02$

Step 4 – divide: $\sigma = \dfrac{2 \times 10^6}{0.02}$

Step 5 – evaluate: $\sigma = 1 \times 10^8$ Pa $= 100$ MPa

Step 6 – note: This is half the hoop stress of a cylinder of the same p, d and t, which is why spherical tanks are structurally efficient.

Final Answer: $\sigma = 100$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) **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 in SI units: $E = 200$ 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**:** $EI = 200 \times 10^9 \times 2 \times 10^{-6} = 4 \times 10^5$ N $\cdot$ m^2

Step 3 – multiply by π^2**:** $\pi^2 EI = 9.8696 \times 4 \times 10^5 = 3.948 \times 10^6$

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

Step 5 – divide: $P_{cr} = \dfrac{3.948 \times 10^6}{16}$

Step 6 – evaluate: $P_{cr} = 246730$ N ≈ 247 kN

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

Answer: (D) **Go Back to Q28**

Q29.

Solution

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

Step 1 – list the data: $\sigma_x = 90$ MPa, $\sigma_y = 30$ MPa, $\tau_{xy} = 40$ MPa.

Step 2 – compute the average stress: $\dfrac{\sigma_x + \sigma_y}{2} = \dfrac{90+30}{2} = 60$ MPa

Step 3 – compute the half-difference: $\dfrac{\sigma_x - \sigma_y}{2} = \dfrac{90-30}{2} = 30$ MPa

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

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

Step 5 – take the minus sign for the minor principal stress: $\sigma_2 = 60 - 50$

Step 6 – evaluate: $\sigma_2 = 10$ MPa

Final Answer: $\sigma_2 = 10 \text{ MPa} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept – strain energy stored in torsion: $U = \dfrac{T^2 L}{2GJ}$, with $J = \dfrac{\pi d^4}{32}$.

Step 1 – list the data in SI units: $T = 1$ kN·m $= 1000$ N·m, $L = 2$ m, $G = 80 \times 10^9$ Pa, $d = 50$ mm $= 0.05$ m.

Step 2 – compute J: $d^4 = 0.05^4 = 6.25 \times 10^{-6}$ m^4

$J = \dfrac{\pi \times 6.25 \times 10^{-6}}{32} = 6.136 \times 10^{-7}$ m^4

Step 3 – form GJ: $GJ = 80 \times 10^9 \times 6.136 \times 10^{-7} = 49087 \text{ N} \cdot \text{m}^2$

Step 4 – form the numerator T^2L: $T^2 = 1000^2 = 1 \times 10^6$

$T^2 L = 1 \times 10^6 \times 2 = 2 \times 10^6$

Step 5 – form the denominator $2GJ$: $2GJ = 2 \times 49087 = 98174$

Step 6 – divide: $U = \dfrac{2 \times 10^6}{98174} = 20.4$ J

Final Answer: $U \approx 20.4 \text{ J} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – natural frequency of a spring–mass system: $\omega_n = \sqrt{\frac{k}{m}}$.

Step 1 – list the data: $k = 5000$ N/m, $m = 5$ kg.

Step 2 – form the ratio k/m**:** $\frac{k}{m} = \frac{5000}{5} = 1000\ \mathrm{s}^{-2}$

Step 3 – take the square root: $\omega_n = \sqrt{1000}$

Step 4 – evaluate: $\omega_n = 31.62 \approx 31.6$ rad/s

Final Answer: $\omega_n \approx 31.6$ rad/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q31

Q32.

Solution

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

Step 1 – list the data: $T = 800$ N·m, $A_m = 0.02$ m^2.

Step 2 – form the denominator $2A_m$**:** $2A_m = 2 \times 0.02 = 0.04$ m^2

Step 3 – divide: $q = \frac{800}{0.04}$

Step 4 – evaluate: $q = 20000$ N/m $= 20$ kN/m

Final Answer: $q = 20$ kN/m $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q32

Q33.

Solution

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

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

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

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

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

Step 5 – form the denominator $48EI$: $48EI = 48 \times 4 \times 10^5 = 1.92 \times 10^7$

Step 6 – divide: $\delta = \dfrac{16000}{1.92 \times 10^7} = 8.33 \times 10^{-4}$ m

Step 7 – convert to millimetres: $\delta = 0.833$ mm

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

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – orientation of the principal plane: $\tan 2\theta_p = \dfrac{2\tau_{xy}}{\sigma_x - \sigma_y}$.

Step 1 – list the data: $\sigma_x = 80$ MPa, $\sigma_y = 20$ MPa, $\tau_{xy} = 30$ MPa.

Step 2 – form the numerator $2\tau_{xy}$: $2 \times 30 = 60$

Step 3 – form the denominator $\sigma_x - \sigma_y$: $80 - 20 = 60$

Step 4 – form the ratio: $\tan 2\theta_p = \dfrac{60}{60} = 1$

Step 5 – take the inverse tangent: $2\theta_p = \tan^{-1}(1) = 45°$

Step 6 – halve: $\theta_p = 22.5°$

Final Answer: $\theta_p = 22.5° \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

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

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

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: $10^{0.2857} = 1.9307$

Step 4 – take the reciprocal: $r_p^{-0.2857} = \dfrac{1}{1.9307} = 0.5179$

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

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

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

Answer: (B) Go Back to Q35

Q36.

Solution

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

Step 1 – list the data: $V_0 = 250$ m/s, $V_e = 650$ m/s.

Step 2 – write the expression: $\dfrac{F}{\dot{m}} = V_e - V_0$

Step 3 – substitute the numbers: $\dfrac{F}{\dot{m}} = 650 - 250$

Step 4 – evaluate: $\dfrac{F}{\dot{m}} = 400$ N·s/kg

Final Answer: $F/\dot{m} = 400$ N·s/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept – heat added in a combustor: $q = c_p\,\Delta T_0 = c_p\,(T_{03} - T_{02})$.

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

Step 5 – convert to kJ/kg: $q = 603$ kJ/kg

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

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – nozzle exit velocity from the energy equation: 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 $2c_p\,\Delta T$: $2 \times 1005 \times 300$

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

$2010 \times 300 = 603000$

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

Step 5 – evaluate: $V_e = 776.5 \approx 776$ m/s

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

Answer: (A) Go Back to Q38

Q39.

Solution

Concept – critical (throat) temperature ratio at $M = 1$: $\dfrac{T^*}{T_0} = \dfrac{2}{\gamma + 1}$.

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

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

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

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

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

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – compressor power: $P = \dot{m}\, c_p\, \Delta T_0$.

Step 1 – list the data: $\dot{m} = 15$ kg/s, $c_p = 1005$ J/kg · K, $\Delta T_0 = 200$ K.

Step 2 – form $\dot{m}\, c_p$: $15 \times 1005 = 15075$

Step 3 – multiply by the temperature rise: $P = 15075 \times 200$

Step 4 – evaluate: $P = 3015000$ W

Step 5 – convert to megawatts: $P = 3.02$ MW

Final Answer: $P \approx 3.02$ MW $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q40

Q41.

Solution

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

Step 1 – list the data: $\dot{m} = 100$ kg/s, $V_e = 2800$ m/s, $p_e = 100$ kPa, $p_a = 50$ kPa, $A_e = 0.5$ m^2.

Step 2 – compute the momentum thrust: $\dot{m}V_e = 100 \times 2800 = 280000$ N

Step 3 – compute the pressure difference: $p_e - p_a = 100 - 50 = 50$ kPa $= 50000$ Pa

Step 4 – compute the pressure thrust: $(p_e - p_a)A_e = 50000 \times 0.5 = 25000$ N

Step 5 – add the two contributions: $F = 280000 + 25000 = 305000$ N

Step 6 – convert to kilonewtons: $F = 305$ kN

Final Answer: $F = 305$ kN $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q41

Q42.

Solution

Concept – effective exhaust velocity from specific impulse: $V_e = I_{sp}\, g_0$.

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

Step 2 – write the expression: $V_e = I_{sp}\, g_0$

Step 3 – substitute the numbers: $V_e = 250 \times 9.81$

Step 4 – evaluate: $V_e = 2452.5 \approx 2452$ m/s

Final Answer: $V_e \approx 2452$ m/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – Tsiolkovsky rocket equation, solved for the mass ratio: $\Delta v = I_{sp}\, g_0 \ln\left(\frac{m_0}{m_f}\right)$, so $\frac{m_0}{m_f} = e^{\Delta v/(I_{sp} g_0)}$.

Step 1 – list the data: $\Delta v = 4905$ m/s, $I_{sp} = 250$ s, $g_0 = 9.81$ m/s^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 – form the exponent $\Delta v/(I_{sp}g_0)$: $\dfrac{4905}{2452.5} = 2.0$

Step 4 – exponentiate: $\dfrac{m_0}{m_f} = e^{2.0}$

Step 5 – evaluate: $\dfrac{m_0}{m_f} = 7.389 \approx 7.39$

Final Answer: $m_0/m_f \approx 7.39 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q43

Q44.

Solution

Concept – fuel–air ratio: $f = \dfrac{\dot{m}_f}{\dot{m}_a}$.

Step 1 – list the data: $\dot{m}_a = 50$ kg/s, $\dot{m}_f = 1$ kg/s.

Step 2 – form the ratio: $f = \dfrac{1}{50}$

Step 3 – evaluate: $f = 0.02$

Step 4 – interpret: A fuel–air ratio of 0.02 (i.e. $1{:}50$) is typical of the lean overall mixture in a gas-turbine combustor.

Final Answer: $f = 0.02 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – thrust (propulsive) power: The useful propulsive power is the thrust times the flight speed, $P = F\,V_0$.

Step 1 – list the data: $F = 20$ kN $= 20000$ N, $V_0 = 250$ m/s.

Step 2 – write the expression: $P = F\,V_0$

Step 3 – substitute the numbers: $P = 20000 \times 250$

Step 4 – evaluate: $P = 5000000$ W

Step 5 – convert to megawatts: $P = 5$ MW

Final Answer: $P = 5$ MW $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – isentropic turbine expansion temperature: $\dfrac{T_{04}}{T_{03}} = \left(\dfrac{1}{r_p}\right)^{(\gamma-1)/\gamma} = r_p^{-(\gamma-1)/\gamma}$.

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

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: $8^{0.2857} = 1.8114$

Step 4 – take the reciprocal: $r_p^{-0.2857} = \dfrac{1}{1.8114} = 0.5521$

Step 5 – multiply by the inlet temperature: $T_{04} = 1200 \times 0.5521$

Step 6 – evaluate: $T_{04} = 662.5 \approx 662$ K

Final Answer: $T_{04} \approx 662$ K $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q46

Answer Key

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