AE - 2022

AI24BTECH11015 - Harshvardhan Patidar

1) Consider a conventional subsonic fixed-wing airplane. e is the Oswald efficiencyfactor and AR is the aspect ratio. Corresponding to the minimum $\left(\frac{C_D}{C_L^{3/2}}\right)$, which of the following relations is true?
   a) $\frac{C_D}{C_L^2} = \frac{1}{\pi e AR}$
   b) $\frac{C_D}{C_L^2} = \frac{4}{\pi e AR}$
   c) $\frac{C_D}{C_L} = \frac{1}{\pi e AR}$
   d) $\frac{C_D}{\sqrt{C_L}} = \frac{1}{\sqrt{\pi e AR}}$
2) A horizontal load F is applied at point R on a two-member truss, as shown in the figure 2.1. Both the members are prismatic with cross-sectional area, A_0, and made of the same material with Young's modulus E.
   The horizontal displacement of point R is:

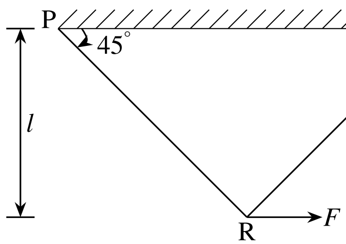

Fig. 2.1

   a) 0
   b) $\frac{Fl}{EA_0}$
   c) $\sqrt{2}\frac{Fl}{EA_0}$
   d) $2\frac{Fl}{EA_0}$
3) Which of the following is **NOT** always true for a combustion process taking place in a closed system?
   a) Total number of atoms is conserved
   b) Total number of molecules is conserved
   c) Total number of atoms of each element is conserved
   d) Total mass is conserved
4) The real function $y = \sin^2(|x|)$ is
   a) continuous for all x
   b) differentiable for all x
   c) not continuous at $x = 0$

d) not differentiable at $x = 0$

5) A convergent nozzle fed from a constant pressure, constant temperature reservoir, is discharging air to atmosphere at 1 bar (absolute) with choked flow at the exit (marked as Q)
Flow through the nozzle can be assumed to be isentropic.
If the exit area of the nozzle is increased while all the reservoir parameters and ambient conditions remain the same, then at steady state

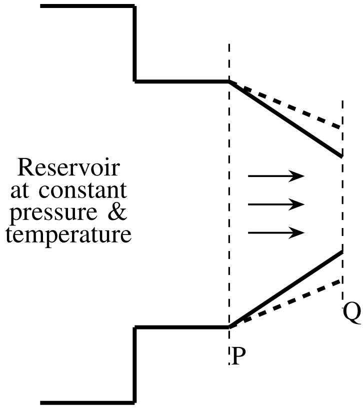

Fig. 5.1

a) the nozzle will remain choked
b) the nozzle will be un-choked
c) the Mach number at section P will increase
d) the Mach number at section P will decrease

6) For a conventional airplane in straight, level, constant velocity flight condition, which of the following condition(s) is/are possible on Euler angles (ϕ, θ, ψ), angle of attack (α) and the sideslip angle (β)?

a) $\phi = 0^\circ, \theta = 2^\circ, \psi = 0^\circ, \alpha = 2^\circ, \beta = 0^\circ$
b) $\phi = 5^\circ, \theta = 0^\circ, \psi = 0^\circ, \alpha = 2^\circ, \beta = 0^\circ$
c) $\phi = 0^\circ, \theta = 3^\circ, \psi = 0^\circ, \alpha = 3^\circ, \beta = 5^\circ$
d) $\phi = 0^\circ, \theta = 5^\circ, \psi = 0^\circ, \alpha = 2^\circ, \beta = 5^\circ$

7) Consider a high Earth-orbiting satellite of angular momentum per unit mass $\overrightarrow{h}$ and eccentricity e.
The mass of the Earth is M and G is the universal gravitational constant.
The distance between satellite's center of mass and the Earth's center of mass is r, the true anomaly is θ, and the phase angle is zero.
Which of the following statements is/are true?

a) The trajectory equation is $r = r(\theta) = \frac{\left|\overrightarrow{h}\right|}{GM(1+e\cos\theta)}$
b) The trajectory equation is $r = r(\theta) = \frac{\left|\overrightarrow{h}^2\right|}{GM(1+e\cos\theta)}$

c) $\overrightarrow{h}$ is conserved

d) The sum of potential energy and kinetic energy of the satellite is conserved

8) A rocket operates at an absolute chamber pressure of 20 bar to produce thrust, F_1. The hot exhaust is optimally expanded to 1 bar (absolute pressure) using a convergent-divergent nozzle with exit to throat area ratio $\left(\frac{A_e}{A_t}\right)$ of 3.5 and thrus coefficient, $C_{F,1} = 1.42$.
The same rocket when operated at an absolute chamber pressure of 50 bar produces thrust F_2 and the thrust coefficient is $C_{F,2}$.
Which of the following statements(s) is/are correct?

a) $\frac{F_2}{F_1} = 2.5$

b) $\frac{F_2}{F_1} > 2.5$

c) $\frac{C_{F,2}}{C_{F,1}} = 1$

d) $\frac{C_{F,2}}{C_{F,1}} > 1$

9) $\overrightarrow{v} = x^3\hat{i} + y^3\hat{j} + z^3\hat{k}$ is a vector field where $\hat{i}, \hat{j}, \hat{k}$ are the base vectors of a cartesian coordinate system.
Using the Gauss divergence theorem, the value of the outward flux of the vector field over the surface of a sphere of unit radius centered at the origin is _____ (rounded off to one decimal place).

10) The largest eigenvalue of the given matrix is ______.

$$\begin{pmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{pmatrix}$$

11) A rotational velocity field in air flow is given as $\overrightarrow{V} = ay\hat{i} + bx\hat{j}$, with $a = 10s^{-1}, b = 20s^{-1}$.
The air density is $1.0kg/m^3$ and the pressure at $(x, y) = (0m, 0m)$ is 100kPa.
Neglecting gravity, the pressure at $(x, y) = (6m, 8m)$ is ____ kPA (rounded off to nearest integer).

12) Consider a circulation distribution over a finite wing given by the equation below.

$$\Gamma(y) = \begin{cases} \Gamma_0\left(1 - \frac{2y}{b}\right) \; if \; 0 \leq y \leq \frac{b}{2} \\ \Gamma_0\left(1 + \frac{2y}{b}\right) \; if \; -\frac{b}{2} \leq y \leq 0 \end{cases}$$

The wingspan b is $10m$, the maximum circulation Γ_0 is $20m^2/s$, density of air is $1.2kg/m^3$ and the free stream speed is $80m/s$.
The lift over the left wing is ____ N (rounded off to the nearest integer)

13) Consider a solid cylinder housed inside another cylinder as shown in the figure 13.1. Radius of the inner cylinder is $1m$ and its height is $2m$. The gap between the cylinders is $5mm$ and is filled with a fluid of viscosity 10^{-4} Pa-s.
The inner cylinder is rotating at a constant angular speed of 5 rad/s while the outer cylinder is stationary. Friction at the bottom surfaces can be ignored. Velocity profile in the vertical gap between the cylinders can be assumed to be linear.
The driving moment required for the rotating motion of the inner cylinder is ____ Nm (rounded off to two decimal places).

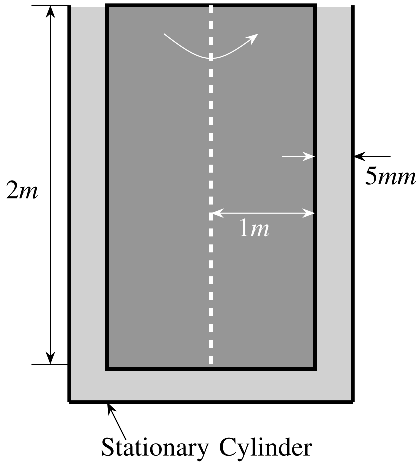

Fig. 13.1