(1 Mark Questions)

1. If M is the Mach number of the flow, M^* is the characteristic Mach number and γ is the ratio of specific heats, then as $M \to \infty$, $M^* \to$?

(a) $\dfrac{\gamma+1}{\gamma-1}$ (b) $\sqrt{\dfrac{\gamma-1}{\gamma+1}}$

(c) $\dfrac{2\gamma}{\gamma-1}$ (d) $\sqrt{\dfrac{\gamma+1}{\gamma-1}}$

2. If the velocity potential and the stream function in a two-dimensional potential flow are given by $\phi = r^n \cos n\theta$ and $\psi = r^n \sin n\theta$ then, $n = 2/3$ corresponds to a

(a) uniform flow
(b) flow around a right corner
(c) flow due to a source doublet
(d) flow around a semi-infinite plate

3. Which of the following is not true for a Gouge flap for an aircraft?

(a) It increases wing area
(b) It increases chord length
(c) It does not have a slot effect
(d) It affects trim

4. In the thin airfoil theory, if $x = \dfrac{c}{2}(1 - \cos\theta)$ and the vorticity $\gamma(\theta)$ is written as Fourier series

$$\left[\frac{\gamma(\theta)}{2V} = A_0 \frac{(1+\cos\theta)}{\sin\theta} + \Sigma A_n \sin n\theta\right]$$

Then C_L depends on

(a) A_0
(b) $A_0, A_2, \ldots, A_{2k}, \ldots$
(c) $A_1, A_3, \ldots, A_{2k+1}, \ldots$
(d) A_0, A_1

5. A Sturm-Liouville equation is of the form

$$-\frac{d}{dx}\left[p(x)\frac{dy}{dx}\right] + q(x)\,y = ?$$

(a) $\lambda\, w(x)\, y$ (b) $\lambda\, w(x)$

(c) λy (d) $\lambda^2\, w^2(x)\, y$

where, λ is the eigen value, $w(x)$ is the weight function and y is the solution.

6. Eigen values of a real symmetric $(n \times n)$ matrix are

(a) all complex conjugates
(b) all real
(c) all unique but not all real
(d) not unique

7. If the body forces are zero and the Airy's stress function is defined by

$$\sigma_x = \partial^2\phi/\partial y^2,\ \sigma_y = \frac{\partial^2\phi}{\partial x^2},\ \tau_{xy} = \frac{-\partial^2\phi}{\partial x \partial y}$$

then, which of the following is true?

(a) $\frac{\partial \phi}{\partial x} + \frac{\partial \phi}{\partial y} = 0$ (b) $\nabla^2 \phi = 0$

(c) $\nabla^2 \phi - \frac{\partial^2 \phi}{\partial x \partial y} = 0$ (d) $\nabla^4 \phi = 0$

8. In a turboprop engine, the propeller is powered by
(a) reciprocating engine (b) a free turbine
(c) compressor shaft (d) air-borne IC engines

9. If the Mach number at a cross-section of a nozzle is $M = 0.8$ and ratio of specific heat is $\gamma = 1.4$, then $A/A^* = ?$ (where, A^* is the cross-sectional area of the throat.
(a) 1.4 (b) 1.3
(c) 1.04 (d) 1.004

10. In a turbojet engine, thrust specific fuel consumption ..... with increasing compressor pressure ratio and ..... with increasing turbine inlet temperature (within range of operation).
(a) decreases, decreases (b) decreases, increases
(c) increases, increases (d) increases, decreases

11. In a liquid fuelled engine (rocket), the exhaust velocity v_e depends on the molecular weight of the propellant M_e as

(a) M_e (b) $\frac{1}{M_e^2}$

(c) $\frac{1}{M_e}$ (d) $\frac{1}{M_e^{1/2}}$

12. Assuming International Standard Atmosphere conditions, the equations governing troposphere are

$$d\tau = \beta\, dh$$

$$\frac{dp}{p} = k_1\, dh$$

$$\frac{d\rho}{\rho} = k_2\, dh$$

(a) $k_1 = \frac{-g\beta}{\tau}$, $k_2 = \frac{-g + R\beta}{\tau}$

(b) $k_1 = \frac{-g}{R\tau}$, $k_2 = -\left(\frac{g}{R} - \beta\right) \times \frac{1}{\tau}$

(c) $k_1 = \frac{-g}{R\tau}$, $k_2 = -\left(\frac{g}{R} + \beta\right) \times \frac{1}{\tau}$

(d) $k_1 = \frac{g}{R\tau}$, $k_2 = \left(\frac{g}{R} + \beta\right) \times \frac{1}{\tau}$

13. Slat is a leading edge high lift device used for minimizing take-off and landing distances. A slat
(a) increases α_{0_L}, decreases $C_{L\alpha}$
(b) increases α_{0_L}, increases $C_{L\alpha}$
(c) increases $C_{L\alpha}$
(d) increases $C_{L\max}$

14. In the Lanchester model of the Phugoid mode, the approximate phugoid frequency is given by the expression $\omega = g\frac{k}{u}$, where the value of constant k is equal to

(a) $\frac{1}{\sqrt{2}}$ (b) 2

(c) $\sqrt{3}$ (d) $\sqrt{2}$

15. In the combustion chamber of a jet engine, the CO_2 emission in the diffusion flame is maximum at an equivalence ratio (ϕ) with value equal to
(a) 0.7 (b) 0.2
(c) 0.75 (d) 0.9

16. The centre of gravity position, where the elevator angle is independent of the load factor n of the manoeuvre is

(a) $\bar{x}_n - \frac{2C_{m_q}}{\mu}$ (b) $\bar{x}_n + \frac{2C_{m_q}}{\mu}$

(c) $\bar{x}_n - \frac{C_{m_q}}{\mu}$ (d) $\bar{x}_n - \frac{C_{m_q}}{2\mu}$

where, μ = non-dimensionalized mass

$\bar{x}_n$ = neutral point, $C_{m_q} = \frac{\partial C_m}{\partial \hat{\mathbf{q}}}$

17. The governing equation of a two-body orbital motion, where, $\vec{\mathbf{r}}$ is the vector joining the centre of masses of the two bodies is given by

(a) $\frac{d^2\vec{\mathbf{r}}}{dt^2} + \frac{k\vec{\mathbf{r}}}{|\vec{\mathbf{r}}|^2} = 0$ (b) $\frac{d^2\vec{\mathbf{r}}}{dt^2} + \frac{k\vec{\mathbf{r}}}{|\vec{\mathbf{r}}|^3} = 0$

(c) $\frac{d^2\vec{\mathbf{r}}}{dt^2} - \frac{k\vec{\mathbf{r}}}{|\vec{\mathbf{r}}|^2} = 0$ (d) $\frac{d^2\vec{\mathbf{r}}}{dt^2} + \frac{k\vec{\mathbf{r}}}{|\vec{\mathbf{r}}|} = 0$

where, $k > 0$.

18. If the radius of apogee r_a of the orbit of a celestial body is thrice the radius of perigee r_p, then the eccentricity of the elliptical orbit is
(a) 3 (b) 0.5
(c) 0.333 (d) 0.25

19. For torsion of a bar of elliptic cross-section with major axis a and minor axis b, for an applied torque T, the twist per unit length $\frac{d\theta}{dz}$ is given by the expression $\frac{d\theta}{dz} = \frac{T}{GK}$, where k is

(a) $\frac{\pi a^2 b^2}{(a^2 + b^2)}$ (b) $\frac{\pi a^4 b^2}{(a^2 + b^2)}$

(c) $\frac{\pi a^4 b^2}{(a^3 + b^3)}$ (d) $\frac{\pi a^3 b^3}{(a^2 + b^2)}$

20. If P_{cr} (buckling) for an Euler column with both ends hinged is P, then critical buckling force for the same column with both ends clamped is
(a) $2P$ (b) $P/2$
(c) $P/4$ (d) $4P$

21. For lateral and directional static stability of an aircraft, which of the following is true?
(a) $L_\beta < 0, N_\beta < 0$ (b) $L_\beta > 0, N_\beta > 0$
(c) $L_\beta < 0, N_\beta > 0$ (d) $L_\beta > 0, N_\beta < 0$

22. For a minimum length nozzle, the expansion angle of the wall downstream of the throat θ_w depends upon Prandtl-Meyer function of the design exit Mach number as
(a) v_M^2 (b) $2v_M$
(c) $v_M/4$ (d) $v_M/2$

23. Using a Joukowski transform on a circular cylinder to obtain a two-dimentional Joukowski airfoil, the complex velocity ω in the new plane Z depends on velocity $\tilde{\omega}$ in the original plane ξ as
(a) $\omega(1 - \xi^2)$ (b) ω/ξ^2
(c) $\omega/(1 - \xi^2)$ (d) $\omega/(1 - 1/\xi^2)$

24. A system with characteristic equation $s^2 + 2s + 2 = 0$ if perturbed, crosses the equilibrium line
(a) never
(b) infinite times
(c) once
(d) doesn't cross; attains equilibrium

25. If n moles of water is heated from temperature T_1 to kT_1, where $k > 1$ from a reservoir at temperature T_R, then entropy change of reservoir during this process will be
(a) $nC_V \ln k$ (b) $-nC_V \ln k$
(c) $-nC_V \ln T_R/T_1$ (d) $-\dfrac{nC_p T_1 (k-1)}{T_R}$

26. The critical buckling load for a Euler column clamped on one end and pinned on the other is given as $P_{cr} = \dfrac{k' EI}{l^2}$, where the parameters E, I and l have their usual meanings. Then, the value of k' (correct to 1st decimal digit)
(a) 2.36 (b) 20.2
(c) 10.6 (d) 30.2

27. If the degree of reaction at mid-radius of compressor is 0.5 and hub-to-tip ratio is 0.6, then the degree of reaction of the compressor at blade tip is (correct to two decimal places)
(a) 0.68 (b) 1.2
(c) 0.2 (d) 1.9

28. If in a shock tube, there exists a series of expansion waves propagating in air ($\gamma = 1.4$) such that the first and the last expansion waves have the same velocity (equivalent to single expansion wave), the pressure ratio between the head and tail of wave is (correct to 2 decimal places)
(a) 0.21 (b) 2.0
(c) 1.6 (d) 1.0

29. Given the following data table for an airfoil (the airfoil is cambered):

α_G	C_L	C_M
2°	0.3	0.75
5°	0.6	0.50

The non-dimensionalized pitching moment about the aerodynamic centre $C_{M_{AC}}$ is estimated as (correct to 2 places of decimal).
(a) 2.5 (b) 0.6
(c) 2.00 (d) 1.00

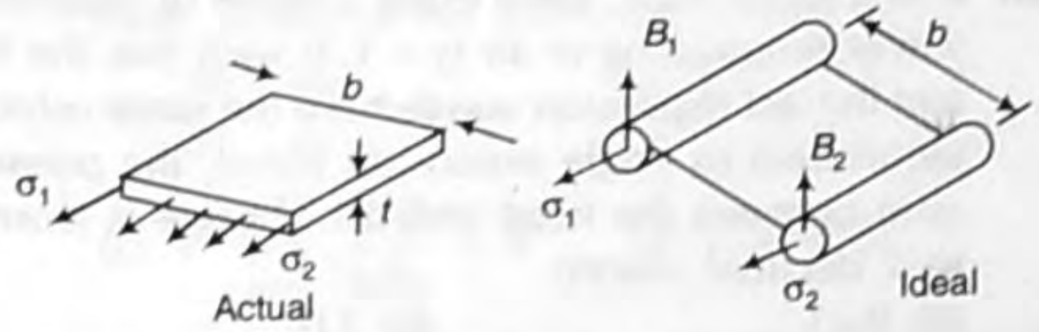
30. If the specific work done on an ideal gas reversibly is 59.4 J/kg and the process is a polytropic process of the form pV^m, then m is (given that the temperature of the gas increases by 50 K.)
(m is an integer)
(a) 6 (b) 2
(c) 8 (d) 4

31. The velocity vector of an aircraft along the body fixed axis is given as $\vec{V} = [u\ v\ w]^T$. If the angle of attack is 5° and sideslip is 2°, then given that velocity vector modulus is 100 m/s, which of the following is true?
(a) $u = 89.56$ m/s, $v = 3.48$ m/s
(b) $w = 7.81$ m/s, $v = 3.48$ m/s
(c) $u = 99.56$ m/s, $w = 7.81$ m/s
(d) $u = 99.56$ m/s, $w = 8.71$ m/s

32. For an aircraft in steady flight, if the zero lift drag coefficient is 0.018, aspect ratio is 8, Ostwald's efficiency factor is 0.9, then what is the maximum lift to drag ratio the aircraft can maintain under such conditions?
(a) 80 (b) 25
(c) 44 (d) 71

33. If 1 and 2 (subscripts) denote the conditions before and after a stationary normal shock, which of the following statements is true w.r.t. a normal shock?
(a) $\rho_1 u_2 = \rho_2 u_1$ (b) $M_1^* M_2^* = 1$
(c) $\rho_1 u_2^2 = \rho_2 u_1^2$ (d) $M_1^* = M_2^*$

34. The panel of an aerospace structure is idealized in the form of boom and skin as shown below.



(B_1 and B_2 are boom areas)

Then, $\frac{B_1}{B_2}$ is equal to

(a) $\frac{\sigma_1/\sigma_2 + 1}{\sigma_2/\sigma_1}$ (b) $\frac{\sigma_1/\sigma_2 + 1}{\sigma_2/\sigma_1 + 1}$

(c) $\frac{\sigma_2/\sigma_1 + 2}{\sigma_1/\sigma_2 + 2}$ (d) $\frac{\sigma_2}{\sigma_1} + 2$

35. If the load factor n at the lowest point of a steady pull-out is 9.0 and the radius of curvature of the flight path during the pull-out is 200 m, then the velocity of the aeroplane during the pull-out is

(a) 127 m/s (b) 123 m/s
(c) 125 m/s (d) 152 m/s

36. The eigen value corresponding to the approximate spiral mode λ equals to

(a) $N_\gamma - \frac{L_\gamma L_\beta}{L_p^2} N_\beta$ (b) $N_\beta - \frac{L_\beta}{L_\gamma} N_\gamma$

(c) $N_\gamma - \frac{L_\gamma}{L_\beta} N_\beta$ (d) $N_\gamma + \frac{L_\beta}{L_\gamma} N_\beta$

where, $N_\gamma = \frac{\partial N}{J_{ZZ}\,\partial\gamma}$, $N_\beta = \frac{\partial N}{J_{ZZ}\,\partial\beta}$, $L_\gamma = \frac{\partial L}{J_{XX}\,\partial\gamma}$,

$L_\beta = \frac{\partial L}{J_{XX}\,\partial\beta}$

37. If subscript 2 denotes the compressor inlet, subscript 4 denotes the turbine inlet, η_c and η_t denote the compressor and turbine efficiencies respectively, then

$\left(\frac{\pi_c^{\frac{\gamma-1}{\gamma}} - 1}{1 - \pi_t^{\frac{\gamma-1}{\gamma}}}\right)$ = ?, If π indicates the pressure ratio across the component.

(a) $\frac{\eta_c}{\eta_t}\frac{T_{04}}{T_{02}}$ (b) $\frac{\eta_t}{\eta_c}\frac{T_{02}}{T_{04}}$

(c) $\frac{\eta_c \eta_t\, T_{02}}{T_{04}}$ (d) $\frac{\eta_c \eta_T\, T_{04}}{T_{02}}$

(γ is the ratio of specific heats)

38. The velocity induced by a directed segment $d\vec{l}$ of a vortex filament is given by $d\vec{v}$ = ? where, symbols have their usual meanings.

(a) $\frac{\Gamma}{2\pi}\frac{d\vec{l} \times \vec{r}}{|r|^2}$ (b) $\frac{\Gamma}{4\pi}\frac{(d\vec{l} \cdot \vec{r})\,\vec{r}}{|r|^3}$

(c) $\frac{\Gamma}{2\pi}\frac{d\vec{l} \times \vec{r}}{|r|^4}$ (d) $\frac{\Gamma}{4\pi}\frac{d\vec{l} \times \vec{r}}{|r|^3}$

39. Consider a venturi with throat to inlet area 0.8 mounted in a flow at standard sea level conditions. If the pressure difference between the inlet and the throat is 20 Pa, the velocity of the flow at the inlet is

(a) 16.6 m/s (b) 17.1 m/s
(c) 18 m/s (d) 18.2 m/s

40. For an initial value problem $y' = f(t, y)$ and $y(t_0) = y_0$, the 4th order Runge-Kutta method is given by the equations

$$y_{n+1} = y_n + \frac{h}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

$$t_{n+1} = t_{n+h}$$

If $k_1 = f(t_n, y_n)$, k_4 = ?

(a) $f(t_n + h/2, y_n + hk_2)$
(b) $f(t_n + h, y_n + hk_3)$
(c) $f(t_n, y_n + hk_1)$
(d) $f(t_n + h/2, y_n + hk_2/2)$

41. Given, an iteration of the form

$$x_{n+1} = x_n - \frac{f'(x_n)}{f''(x_n)}$$

Then, after a large number of iterations, $x_n \to x$ (within an error bound) such that

(a) $f(x) = 0$ (b) $f(x) = f'(x)$

(c) $f''(x) - \frac{f'(x)}{f(x)} = 0$ (d) $f'(x) = 0$

42. If the stagnation temperature T_0 at compressor inlet is increased 1.44 times and stagnation pressure p_0 is decreased to 0.6 times its value, then by what factor should the mass flow rate be decreased in the compressor to achieve the same pressure ratio?

(a) 1.63 (b) 2.11
(c) 2.0 (d) 1.84

43. If the pressure inside the combustion chamber of a rocket engine is p_c, then if p is the pressure at the throat of the rocket nozzle then $\frac{p}{p_c}$ = ? (Given that

the ratio of specific heats γ for the gas stream exhaust is 1.2)

(a) 0.52 (b) 0.59
(c) 0.60 (d) 0.56

44. Given, the following information, determine the maximum range of the steady level flight of the aircraft:

Aircraft design

$$v|D_{min} = 170 \text{ m/s}$$

$$\left(\frac{L}{D}\right)_{max} = 23$$

Propulsion design

$$I_{sp} = 2330 \text{ s}$$

Structural design

$$\frac{W_i}{W_f} = 1.4$$

(a) 3150 km (b) 3105 km
(c) 3065 km (d) 3605 km

45. A uniform supersonic stream with $M_1 = 3.0$ encounters a compression corner that deflects the stream by an angle of 20°. Given that the shock wave angle occurs at 37.5° and that the normal component of the flow (w.r.t. the shock) experiences a normal shock reducing the normal component of the Mach number by 2.989 times, find the downstream Mach number of the flow.

(a) 2.56 (b) 2.22
(c) 2.11 (d) 2.03

46. While estimating contributions of lifting surfaces having elliptic span loadings, to the stability derivatives, integrals of the form

$$I_n = \int_0^1 k^2 \sqrt{1-k^2}\, dk$$

need to be evaluated. Find the value of I_2.

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{12}$

(c) $\frac{\pi}{16}$ (d) $\frac{\pi^2}{8}$

47. For a two-dimensional potential vortex flow, which of the following statement is true?

(a) As $r \to 0$, $|\nabla \times v| \to 0$

(b) $\phi = \frac{\Gamma}{2\pi}\theta$ (if the strength of vortex is Γ)

(c) $\psi = \frac{\Gamma}{2\pi} \ln r$

(d) $\psi = \frac{\Gamma}{8\pi} \ln r$

48. For testing of a small scale model of an aircraft in wind tunnel, the following data is provided:
Actual aircraft Operating flight speed = 200 m/s
Freestream temperature = 220 K
Wind-tunnel model
Freestream temperature = 288 K
The speed of uniform airflow in the wind-tunnel should be

(a) 212 m/s (b) 228 m/s
(c) 202 m/s (d) 200 m/s

49. Assuming that coefficient of viscosity $\mu \propto T^{1/2}$ by what factor should the aircraft be scaled down for constructing the actual model? Given that density of the atmosphere during flight operation is $\frac{1}{4}$th of that in the wind tunnel.

(a) 6 (b) 3
(c) 4 (d) 7

Common Data for Questions 50 and 51

At a given point in a structural member, a two-dimensional stress system exists where $\sigma_X = 60 \text{ N/mm}^2$, $\sigma_Y = -40 \text{ N/mm}^2$ and $\tau_{XY} = 50 \text{ N/mm}^2$. If the Young's modulus $E = 2 \times 10^5 \text{ N/mm}^2$ and Poisson's Ratio $v = 0.3$.

50. The principal strains at that point are

(a) $\varepsilon_I = 495 \times 10^{-6}$, $\varepsilon_{II} = -425 \times 10^{-6}$
(b) $\varepsilon_I = 425 \times 10^{-6}$, $\varepsilon_{II} = -425 \times 10^{-6}$
(c) $\varepsilon_I = 492 \times 10^{-6}$, $\varepsilon_{II} = -492 \times 10^{-6}$
(d) $\varepsilon_I = 427 \times 10^{-6}$, $\varepsilon_{II} = 425 \times 10^{-6}$

51. The inclination of the principal strains to the plane on which σ_X acts, is

(a) 32.5° (b) 22.5°
(c) 42.5° (d) 102.5°

Statements for Linked Answer Questions 52 and 53

Given, a system

$$\dot{X} = AX + B\eta,$$

The state vector solution for the homogeneous response is obtained as

$$X(t) = e^{At} X(0)$$

Now, for control step input

$$\eta(\tau) = \eta_0 H(\tau)$$

where, $$H(\tau) = \begin{cases} 0, & \tau < 0 \\ 1, & \tau \geq 0 \end{cases}$$

(Heaviside step function.)

52. The system response to the step input is

(a) $X(t) = e^{At} AB \eta_0$

(b) $X(t) = e^{At} A^{-1} B \eta_0$

(c) $X(t) = (e^{At} - I) A^{-1} B \eta_0$

(d) $X(t) = (e^{At} - I) AB \eta_0$

53. For the condition that the system is stable, the steady state limit for the step response is $X(t)$ [lim $t \to \infty$] equal to
(a) zero
(b) $AB^{-1}\,\eta_0$
(c) $A^{-1}\,\eta_0$
(d) $-A^{-1}\,B\eta_0$

Statements for Linked Answer Questions 54 and 55

For a satellite orbiting the earth, the semi-major axis of the elliptical orbit is 7888 km and its eccentricity is 0.1.
Given, $\mu_{earth} = 398600.4419\ km^3/s^2$

54. If the true anomaly $\theta = 60°$, then the radius of orbit of the satellite is
(a) 7537 km
(b) 7437 km
(c) 7637 km
(d) 7337 km

55. At the same true anomaly, the velocity magnitude of the satellite is
(a) 7.53 km/s
(b) 7.79 km/s
(c) 7.44 km/s
(d) 7.11 km/s

General Aptitude

56. Which of the following options is the closest in meaning to the word given below?
Mirth
(a) Anger
(b) Merriment
(c) Audacity
(d) Blunder

57. Which of the following options is the closest in meaning to the word given below?
Ruminate
(a) Run fast
(b) Reprimand
(c) Think deeply
(d) Spend lavishly

58. Which of the following options is the farthest in meaning to the word given below?
Confidant
(a) Turncoat
(b) Arrogant
(c) Confederate
(d) Firm

59. Which of the following options is the farthest in meaning to the word given below?
Perfunctory
(a) Quick
(b) Slow
(c) Careful
(d) Loud

60. Which of the following options is the closest in meaning to the word given below?
Prepossessing
(a) Economical
(b) Pleasing
(c) Selfish
(d) Wise

61. Instead of walking along the adjacent sides of a rectangular field, a boy takes a short cut along the diagonal of the field and saves a distance equal to half the longer side. The ratio of the shorter side to that of the longer side is
(a) 1 : 2
(b) 2 : 3
(c) 1 : 4
(d) 3 : 4

62. The proportions of milk and water in two samples are 5 : 2 and 7 : 5. If a mixture comprising of equal quantities of the two samples is made, the proportion of milk and water in the mixture is
(a) 12 : 7
(b) 7 : 12
(c) 109 : 59
(d) 59 : 109

63. An express train moving at a speed of 80 km/h, overtakes a goods train twice as long as the express train and moving in the same direction at a speed of 40 km/h in 54 s. The time taken by express train to go through a station 400 m long is
(a) 27 s
(b) 54 s
(c) 18 s
(d) None of these

64. A child was asked to add first few natural numbers (*i.e.*, 1 + 2 + 3 + ...) so long his patience permitted. As he stopped, he gave the sum as 575. When the teacher declared the result wrong the child discovered he had missed one number in the sequence during addition. The number he missed was
(a) less than 10
(b) 10
(c) 15
(d) more than 15

65. A student took five papers in an examinations, where the full marks were the same for each paper. His marks in these papers were in the proportion of 6 : 7 : 8 : 9 : 10. In all papers together, the candidate obtained 60% of the total marks. Then, the number of papers in which he got more than 50% marks is
(a) 2
(b) 3
(c) 4
(d) 5