GOODWILL GATE2IIT

IIT-JEE | MEDICAL | GATE

GATE 2018

ORGANIZING INSTITUTE :

IIT GUWAHATI

Detailed solution

of

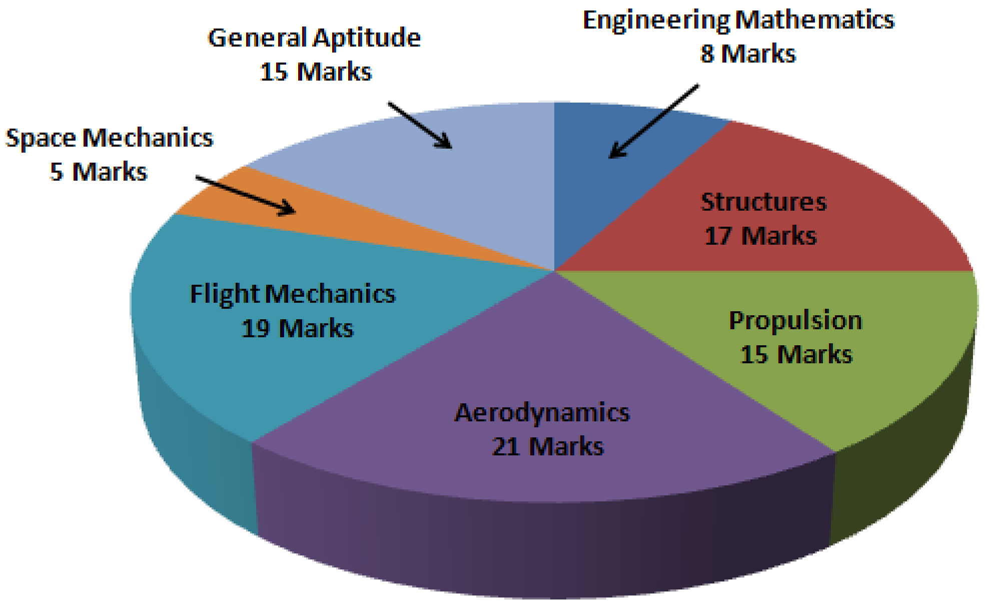
AEROSPACE ENGINEERING

2018

Analysis of GATE

AEROSPACE ENGINEERING

2018



NOTE: *In above distribution,* ***GAS DYNAMICS*** *is part of* ***AERODYNAMICS***

Subject	No of Questions	Topics	Total Marks
Engineering Mathematics	1M : 4 2M : 2	• Matrices • Algebra • Vector calculus • ODE	8
Flight Mechanics	1M : 5 2M : 7	• Atmosphere • Basics – primary flight instruments • Steady straight and level flight • Range and Endurance • Take – off • V-n diagram • Longitudinal static stability • Equations of motion	19
Space Dynamics	1M : 3 2M : 1	• Kepler's Law • Different orbits – Circular	5
Aerodynamics	1M : 7 2M : 7	• Basic Fluid mechanics – Laminar, Boundary layer • Ideal potential flow • Low speed aerodynamics – aerodynamic centre • High lift devices • Finite wing theory • Gas Dynamics – Isentropic flow, Moving NSW, OSW	21
Structures	1M : 3 2M : 7	• Basic Elasticity – Stress tensor, Principal stresses, plane strain • Bending- Symmetrical and unsymmetrical bending, bending stresses • Vibration –undamped and free system 1 DOF system • Energy methods (Indeterminate beam)	17
Propulsion	1M : 3 2M : 6	• Thermodynamics Basics • Axial flow compressor • Axial flow turbine • Centrifugal flow compressor • Jet propulsion – Turbojet Turboprop • Combustion chamber • Rocket propulsion	15
General Aptitude	1M:5 2M:5	• Verbal Ability • Numerical Ability	15
Total	**65**		**100**

1.

Equation of the trajectory of a typical space object around any planet, in polar coordinates (r, θ) (i.e. a general conic section geometry), is given as follows. (h is angular momentum, μ is gravitational parameter, e is eccentricity, r is radial distance from the planet center, θ, is angle between vectors $\vec{e}$ and $\vec{r}$.

(A) $r = \frac{(h^2/\mu)}{1-e\cos\theta}$

(B) $r = \frac{(h^2/\mu)}{e-\cos\theta}$

(C) $r = \frac{(h^2/\mu)}{1+e\cos\theta}$

(D) $r = \frac{(h^2/\mu)}{e+\cos\theta}$

ANS: (C)

This is the orbit equation, and it defines the path of the body m2 around m1, relative to m1. Remember that m, h, and e are constants. Observe as well that there is no significance to negative values of eccentricity, that is, $e \geq 0$. Since the orbit equation describes conic sections, including ellipses, **it is a mathematical statement of Kepler's first law, namely, that the planets follow elliptical paths around the sun.** Two-body orbits are often referred to as Keplerian orbits.

2.

The pilot of a conventional airplane that is flying steady and level at some altitude, deflects the port side aileron up and the starboard aileron down. The aircraft will then

(A) pitch, nose up.
(B) roll with the starboard wing up.
(C) pitch, nose down.
(D) roll with the port wing up.

ANS: (B)

As the port side aileron is deflected upwards, it will produce a lift force in downward direction, the starboard aileron is deflected downwards, producing lift force in the upward direction. Hence, the aircraft will roll with the starboard wing up.

3.

In an elliptic orbit around any planet, the location at which a spacecraft has the maximum angular velocity is

(A) apoapsis. (B) periapsis.
(C) a point at +45° from periapsis. (D) a point at –90° from apoapsis.

ANS: (B)

The angular momentum depends only on the **azimuthal (perpendicular or transverse) component of the relative velocity and is constant for an orbit.**

$$h = rV_T = \text{constant}$$

The larger the value of r, i.e. farthest position (apoapsis) of the mass, the velocity is minimum and the smaller the value of r, i.e. closest position (Periapsis) of the mass, the velocity is maximum.

4.

A jet aircraft is initially flying steady and level at its maximum endurance condition. For the aircraft to fly steady and level, but faster at the same altitude, the pilot should

(A) increase thrust alone.
(B) increase thrust and increase angle of attack.
(C) increase thrust and reduce angle of attack.
(D) reduce angle of attack alone.

ANS: (C)

To move faster the pilot has to increase the thrust of an aircraft. But as thrust increases, velocity increases, which in turn increases the lift. As usually the aerodynamic centre is ahead of the c.g. of an aircraft, it will produce a nose up pitching moment. To maintain steady and level flight, the pilot has to decrease angle of attack to compensate for the additional lift.

5.

The tangential velocity component 'V' of a spacecraft, which is in a circular orbit of radius 'R' around a spherical Earth (μ = GM → gravitational parameter of Earth) is given by the following expression.

(A) $V = \sqrt{\frac{\mu}{2R}}$ (B) $V = \sqrt{\frac{\mu}{R}}$ (C) $V = \frac{2\pi}{\sqrt{\mu}} R^{\frac{3}{2}}$ (D) $V = \frac{2\pi}{\sqrt{\mu}} R^{\frac{2}{3}}$

ANS: B

Setting e = 0 in the orbital equation,

$$r = \frac{h^2}{\mu} \frac{1}{1 + eCos\theta}$$

We get,

$$r = \frac{h^2}{\mu}$$

That is, r = constant, which means the orbit of m2 around m1 is a circle. Since the radial velocity V_r is zero, it follows that V = V_T so that the angular momentum formula h = r$V_T$becomes simply h = rV for a circular orbit. Substituting in above expression, we get,

$$r = \frac{r^2 V^2}{\mu}$$

$$V_{circular} = \sqrt{\frac{\mu}{r}}$$

6.

A combustor is operating with a fuel-air ratio of 0.03. If the stoichiometric fuel-air ratio of the fuel used is 0.06, the equivalence ratio of the combustor will be _______ (accurate to two decimal places).

ANS: 0.50

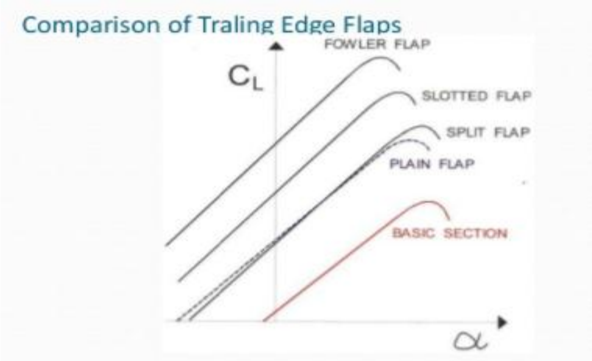
$$Equivalence\ ratio = \frac{(\frac{f}{A})_{actual}}{(\frac{f}{A})_{stio}} = \frac{0.03}{0.06} = 0.50$$

7.

A NACA 0012 airfoil has a trailing edge flap. The airfoil is operating at an angle of attack of 5 degrees with un-deflected flap. If the flap is now deflected by 5 degrees downwards, the C_L versus α curve

(A) shifts right and slope increases.
(B) shifts left and slope increases.
(C) shifts left and slope stays the same.
(D) shifts right and slope stays the same.

ANS: (c)



8.

The determinant of the matrix $\begin{bmatrix} 1 & 1 & -1 \\ 2 & 1 & 0 \\ 3 & 1 & 1 \end{bmatrix}$ is ______ (accurate to one decimal place).

ANS: 0

9.

The theoretical maximum velocity (in m/s) of air expanding from a reservoir at 700 K is __________ (accurate to two decimal places). Specific heat of air at constant pressure is 1005 J/(kg-K).

ANS: 1186.17

$$C_{max} = \sqrt{2C_pT_0} = 1186.17\ m/s$$

10.

For a damped single degree of freedom system with damping ratio of 0.1, ratio of two successive peak amplitudes of free vibration is __________ (accurate to two decimal places).

ANS: 1.88

LOGARITHMIC DECREMENT

It represents the rate at which the amplitude of a free damped vibration decreases.

$$\delta = \ln\left(\frac{x_1}{x_2}\right) = \xi\omega_n t_d = \frac{2\pi\xi}{\sqrt{1-\xi^2}}$$

$$\frac{x_1}{x_2} = 1.88$$

11.

The pitching moment of a positively cambered NACA airfoil about its leading edge at zero-lift angle of attack is

(A) negative.
(B) positive.
(C) indeterminate.
(D) zero.

ANS: (A)

At zero-lift AOA, a positively cambered NACA airfoil will produce positive lift, resulting in negative pitching moment about its leading edge.

12.

In a low-speed wind tunnel, the angular location(s) from the front stagnation point on a circular cylinder where the static pressure equals the free-stream static pressure, is

(A) $\pm 38^0$ (B) $\pm 30^0$ (C) $\pm 60^0$ (D) 0^0

ANS: (B)

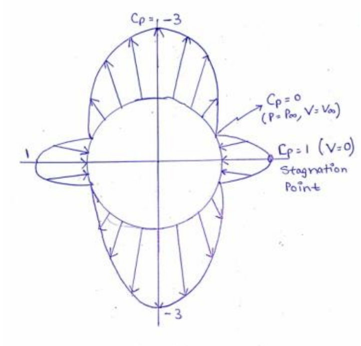
Pressure distribution on a circular cylinder,

$$C_p = \frac{p - p_\infty}{\frac{1}{2}\rho_\infty U^2}$$

Static pressure equals to free- stream pressure, i.e. $C_P = 0$

$$C_p = 1 - 4\sin^2\Theta$$

ϴ (degrees)	0	15	**30**	45	60	75	90
$C_p = 1 - 4\sin^2\theta$	1	0.732	**0**	-1	-2	-2.732	-3



13.

The stagnation pressures at the inlet and exit of a subsonic intake are 100 kPa and 98 kPa, respectively. The pressure recovery of this intake will be _______ (accurate to two decimal places).

ANS: 0.98

$$\text{PRF} = \frac{\text{P01}}{\text{P0a}} = 0.98$$

14.

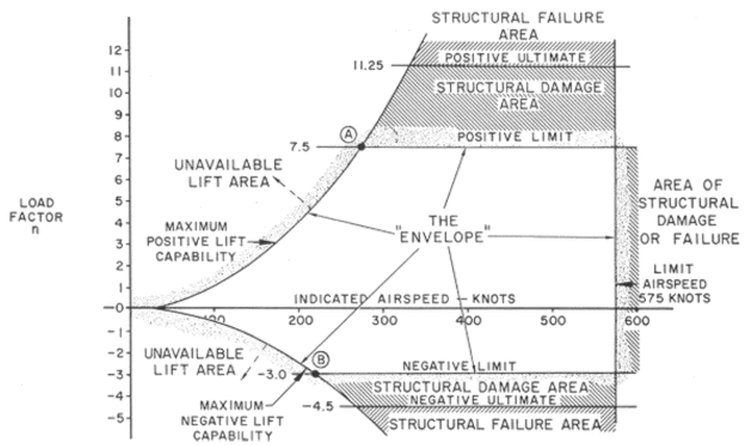
The highest limit load factor experienced by a civil transport aircraft is in the range

(A) 0.0 – 2.0 (B) 2.0 – 5.0 (C) 5.0 – 8.0 (D) 8.0 – 10.0

ANS: (B)

In civil aviation, the maximum maneuvre load factor is typically 2.5 for aircraft weighing less than 50,000 lbs. The appropriate expression to calculate the load factor is as follows:

n = 2.1 + 24000/(W + 10000) upto a maximum of 3.8



15.

In an ideal gas turbine cycle, the expansion in a turbine is represented by

(A) an isenthalpic process.
(B) an isentropic process.
(C) an isobaric process.
(D) an isochoric process.

ANS: (B)

Isentropic process: Entropy remains constant (stagnation pressure and stagnation temperature remains constant)

16.

Determine the correctness or otherwise of the following statements, [a] and [r]:

[a] A closed-section box beam configuration is used in aircraft wings.

[r] Closed-section box beam configuration is capable of resisting torsional loads.

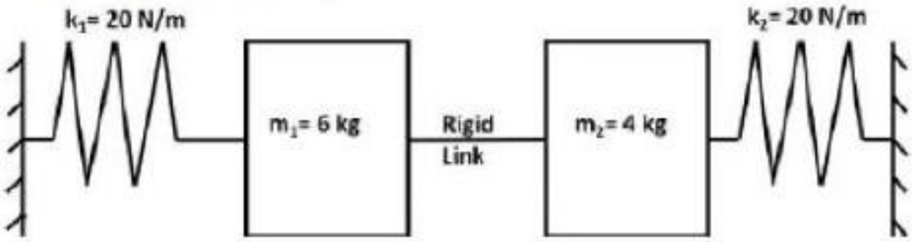
(A) Both [a] and [r] are true and [r] is the correct reason for [a].
(B) Both [a] and [r] are true but [r] is not the correct reason for [a].
(C) Both [a] and [r] are false.
(D) [a] is true but [r] is false.

ANS: (A)

Taking ratio of polar moment of inertia for closed and open cross sections, it can be proved that closed-section beams are more stronger in comparison to open section beams under Torsional loading condition.

17.

The natural frequency (in rad/s) of the spring-mass system shown in the figure below is _____ (accurate to one decimal place).



ANS: 2

Since a rigid link is given within two masses, the given system is one degree of freedom system with springs in parallel

K_{eq} = 20 + 20 = 40 N/m
Mass = 6 + 4 = 10 kg

$$w_n = \sqrt{\frac{k}{m}} = 2\,rad/s$$

18.

The first law of thermodynamics is also known as conservation of

(A) mass.
(B) momentum.
(C) energy.
(D) species.

ANS: (C)

Statement: Energy can neither be created nor be destroyed, but can be transformed from one form to another.

19.

Consider a vector field given by $x\hat{\imath} + y\hat{\jmath} + z\hat{k}$. This vector field is

(A) divergence-free and curl-free.
(B) curl-free but not divergence-free.
(C) divergence-free but not curl-free.
(D) neither divergence-free nor curl-free.

ANS: (B)

Div(r) = 3
Curl (r) = 0 where r = $x\hat{\imath} + y\hat{\jmath} + z\hat{k}$

20.

An airplane requires a longer ground roll to lift-off on hot summer days because

(A) the thrust is directly proportional to free-stream density.
(B) the thrust is directly proportional to weight of the aircraft.
(C) the lift-off distance is directly proportional to free-stream density.
(D) the runway friction is high on hot summer days.

ANS: (A)

$$S_{TO} = \frac{1.21\frac{W}{S}}{\rho g C_{Lmax}\frac{T}{W}}$$

IMPORTANT NOTES:

1. The take-off distance of an airplane is very sensitive to the weight of an airplane through $\frac{W}{S}$ and $\frac{T}{W}$.
   i. Heavier airplanes need longer runway.

$$S_{TO} \propto W^2$$

2. The take-off distance strongly depends on free stream density ρ through both explicit appearance of ρ and the effect of ρ on thrust.

$$S_{TO} \propto \frac{1}{\rho^2} \qquad [T \propto \rho]$$

   i. Takeoff performance of an airplane deteriorates with increasing altitude of the airports.
   ii. Longer takeoff distances are required on hotter days or summer.
   iii. Takeoff performance of an airplane deteriorates with increasing temperature around the airports.
   iv. Takeoff performance is different for airports near equator and poles as ρ increases.

3. The takeoff distance decreases with increase in C_{Lmax}.

$$S_{TO} \propto 1/C_{Lmax}$$

   i. Flaps are deflected at the time of takeoff.

4. Takeoff distance decreases with decrease in wing loading.

5. $$S_{TO} \propto \frac{W}{S}$$

- Smaller wing loadings are expected at the time of takeoff.
- Morphing wings can improve the take off performance.

6. Take-off distance decreases with increase in thrust to weight ratio.

$S_{TO} \propto \frac{1}{T/W}$

i. A high capacity engine improves the takeoff performance of an airplane.
ii. Use of additional disposable rocket motor (RATO) improves the performance of an airplane at the time of takeoff.
iii. Afterburners are used at the time of takeoff or climbing.

21.

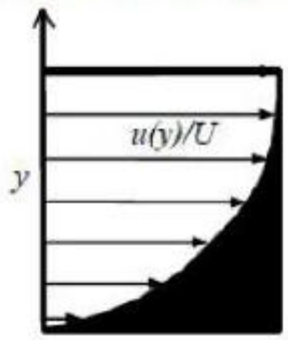
Consider the function $f(x,y) = \frac{x^2}{2} + \frac{y^2}{3} - 5$. All the roots of this function

(A) form a finite set of points.
(B) lie on an elliptical curve.
(C) lie on the surface of a sphere.
(D) lie on a hyperbolic curve.

ANS: (B)

22.

The velocity profile in an incompressible, laminar boundary layer is shown in the figure below. U is the free-stream velocity, $u(y)$ is the stream-wise velocity component. The area of the black shaded region in the figure below represents the



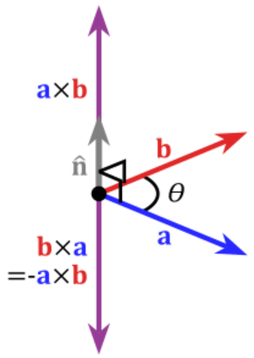
ANS: (C)

23.

Let $\vec{a}, \vec{b}$ be two distinct vectors that are not parallel. The vector $\vec{c} = \vec{a} \times \vec{b}$ is

(A) zero.
(B) orthogonal to $\vec{a}$ alone.
(C) orthogonal to $\vec{a} + \vec{b}$.
(D) orthogonal to $\vec{b}$ alone.

ANS: (C)



24.

A shock wave is moving into still air in a shock tube. Which one of the following happens to the air?

(A) static temperature increases, total temperature remains constant.
(B) static temperature increases, total temperature increases.
(C) static temperature increases, total temperature decreases.
(D) static pressure increases, total temperature remains constant.

ANS: (B)

Static temperature always increases for all types of shock waves
Total temperature increases in case of moving shock, whereas remains constant for standing shocks

25.

A thermocouple, mounted flush in an insulated flat surface in a supersonic laminar flow of air measures the

(A) static temperature.
(B) temperature greater than static but less than total temperature.
(C) total temperature.
(D) temperature greater than total temperature.

ANS: (A)

26.

Which of the following statement(s) is/are true about the state of a body in plane strain condition?

P: All the points in the body undergo displacements in one plane only, for example the x-y plane, leading to $\varepsilon_{zz} = \gamma_{xz} = \gamma_{yz} = 0$.

Q: All the components of stress perpendicular to the plane of deformation, for example the x-y plane, of the body are equal to zero, i.e. $\sigma_{zz} = \tau_{xz} = \tau_{yz} = 0$.

R: Except the normal component, all the other components of stress perpendicular to the plane of deformation of the body, for example the x-y plane, are equal to zero, i.e. $\sigma_{zz} \neq 0$, $\tau_{xz} = \tau_{yz} = 0$.

(A) P only (B) Q only (C) P and Q (D) P and R

ANS: (D)

Plane Strain

- For a plane strain problem, strain components perpendicular to the plane of plane strain condition are zero.
- If xy is the plane of plane strain problem then

Non-zero strain components are $\varepsilon_x, \varepsilon_y, \gamma_{xy}$

Zero strain components are $\varepsilon_z, \gamma_{xz}, \gamma_{yz}$

Non-zero stress components are $\sigma_x, \sigma_y, \sigma_z$ and τ_{xy}

Zero stress components are τ_{xz}, τ_{yz}

27.

A cantilever beam having a rectangular cross-section of width 60 mm and depth 100 mm, is made of aluminum alloy. The material mechanical properties are: Young's modulus, E = 73 GPa and ultimate stress, σ_u = 480 MPa. Assuming a factor of safety of 4, the maximum bending moment (in kN-m) that can be applied on the beam is _____ (accurate to one decimal place).

Ans : 12

E = 73 GP, σ_u = 480 MPa, FOS = 4

$$\sigma_{allow} = \frac{480}{4} = 120 \text{ N/mm}^2 = \frac{M\,y}{I}$$

$$M = \frac{\sigma\, I}{y} = 12 \text{ kN-m}$$

28.

An aircraft with a turboprop engine produces a thrust of 500 N and flies at 100 m/s. If the propeller efficiency is 0.5, the shaft power produced by the engine is

(A) 50 kW (B) 100 kW
(C) 125 kW (D) 500 kW

Ans : (B)

$T = 500$ N
$V = 100$ m/s
$\eta_p = 0.5$

$$P_{available} = T \times V$$
$$= 50 \times 100$$
$$= 50KW$$

$$\eta_P = \frac{P_{available}}{P_{shaft}}$$

$$P_{shaft} = 100 \text{ kW}$$

29.

Consider a 20^0 half-angle wedge in a supersonic flow at Mach 3.0 at standard sea-level conditions. If the shock-wave angle on the wedge is 36^0, the Mach number of the tangential component of the flow post-shock is _______ (accurate to two decimal places).

Ans : 2.16 (question need to be challenged)

$$M_1 = 3$$

$$M_{n1} = M_1 \sin \beta$$
$$= 1.76$$

$$M_{n2}^2 = \frac{2+(\gamma-1)\,M_{n1}^2}{2\,\gamma\,M_{n1}^2-(\gamma-1)}$$
$$\Rightarrow 0.63$$

$$\frac{M_{n2}}{M_{t2}} = \tan(\beta - \theta)$$
$$\Rightarrow M_{t2} = 2.16$$

30.

Consider the vector field $\vec{v} = -\frac{y}{r^2}\,\hat{\imath} + \frac{x}{r^2}\,\hat{\jmath}$; where $r = \sqrt{x^2 + y^2}$. The contour integral $\oint \vec{v} \cdot \overrightarrow{ds}$, where $\overrightarrow{ds}$ is tangent to the contour that encloses the origin, is __________ (accurate to two decimal places).

ANS: 6.28

31.

An aircraft with a turbojet engine flies at a velocity of 100 m/s. If the jet exhaust velocity is 300 m/s, the propulsive efficiency of the engine, assuming a negligible fuel-air ratio, is

(A) 0.33 (B) 0.50 (C) 0.67 (D) 0.80

Ans : (B)

C_i = 100 m/s
C_j = 300 m/s

$$\alpha = \frac{c_i}{c_j} = 0.33$$

$$\eta_p = \frac{2\,\alpha}{1+\alpha} = 0.50$$

32.

An aircraft wind tunnel model, having a pitch axis mass moment of inertia (I_{yy}) of 0.014 kg-m^2, is mounted in such a manner that it has pure pitching motion about its centre of gravity, where it is supported through a frictionless hinge. If the pitching moment (M) derivative with respect to angle of attack (α), denoted by 'M_α', is -0.504 N-m/rad and the pitching moment (M) derivative with respect to pitch rate (q), denoted by 'M_q', is -0.0336 N-m/(rad/s), the damping ratio of the resulting motion due to an initial disturbance in pitch angle is approximately _________ (accurate to three decimal places).

ANS: 0.2

33.

Gross weight of an airplane is 7000 N, wing area is 16 m^2, and the maximum lift coefficient is 2.0. Assuming density at the altitude as 1.23 kg/m^3, the stall speed (in m/s) of the aircraft is ________ (accurate to two decimal places).

Ans : 18.86

W = 7000 N
s = 16 m^2
C_{Lmax} = 2.0
ρ = 1.23 kg/m^3

$$V_{stall} = \sqrt{\frac{2W}{\rho\, s\, C_{Lmax}}} = 18.86 \text{ m/s}$$

34.

The boundary layer thickness at the location of a sensor on a flat plate in an incompressible, laminar flow of air is required to be restricted to 1 mm for an effective measurement. If the flow velocity is 20 m/s with 1 bar pressure, 300 K temperature, and 1.789×10^{-5} kg/(m-s) viscosity, the maximum distance (in mm) of the sensor location from the leading edge is ________ (accurate to one decimal place).

ANS: 51.9

We know, $\delta = \frac{5x}{\sqrt{Re}}$, where $Re = \sqrt{\frac{\rho v x}{\mu}}$

$$\delta = \frac{5x}{\sqrt{\frac{\rho v x}{\mu}}}$$

On solving,
x = 51.9 mm

35.

A pitot probe on an aircraft in a steady, level flight records a pressure of 55,000 N/m^2. The static pressure and density are 45,280 N/m^2 and 0.6 kg/m^3, respectively. The wing area and the lift coefficient are 16 m^2 and 2, respectively. The wing loading (in N/m^2) on this aircraft is ________ (accurate to one decimal place).

Ans : 18076.6 (question need to be challenged)
P_o = 55000 N/m^2
P = 45280 N/m^2
ρ = 0.6 kg/m^2
s =16 m^2
C_L = 2

$$\frac{P_0}{P} = (1 + \frac{\gamma - 1}{2}M^2)^{\frac{\gamma}{\gamma-1}}$$

$$M = 0.534$$

$$M = \frac{V}{\sqrt{\gamma RT}}$$

$$V = 173.57 \text{ m/s}$$

$$L = w = \frac{1}{2}\rho v^2 s C_L$$

$$\Rightarrow \frac{W}{s} = 18076.6 \text{ N/m}^2$$

36.

The solution of the differential equation $\frac{d^2y}{dx^2} + 3\frac{dy}{dx} = 0$, given that $y = 0$ and $\frac{dy}{dx} = 1$ at $x = 0$ is

(A) $x(1 - e^{-3x})$ (B) $\frac{1}{3}(1 - e^{-3x})$ (C) $\frac{1}{3}(1 + e^{-3x})$ (D) $\frac{1}{3}xe^{\frac{-3x}{2}}$

Ans : (B)

$$\frac{d^2y}{dx^2} + 3\frac{dy}{dx} = 0,\ y(0)=0\ \ \frac{dy}{dx}\Big|_{x=0} = 1$$

$$(D^2 + 3D)y = 0$$

Auxiliary equation; $m^2 + 3m = 0$

$$m(m + 3) = 0$$

$$m = 0, -3$$

y = complimentary function + particular integral (P.I. = 0)

$=C_1e^{0\,x} + C_2\,e^{-3x}$

At x=0 , y=0

$0 = C_1 + C_2$

$\Rightarrow C_2 = - C_1$

$y = C_1 - C_1\,e^{-3x}$

$\frac{dy}{dx} = - C_1\,e^{-3x}(-3)$

$\Rightarrow C_1 = \frac{1}{3}$

$\Rightarrow y = \frac{1}{3}\,[1 - e^{-3}$

37.

A statically-stable aircraft has a $C_{L_\alpha} = 5$ (where the angle of attack, α, is measured in radians). The coefficient of moment of the aircraft about the center of gravity is given as $C_{M.c.g} = 0.05 - 4\alpha$. The mean aerodynamic chord of the aircraft wing is 1 m. The location (positive towards the nose) of the neutral point of the aircraft from the center of gravity is _______ (in m, accurate to two decimal places).

Ans : - 0.8

$\frac{dC_L}{d\alpha} = 5$ /radians

$C_{Mcg} = 0.05 - 4\alpha$

c = 1m

$$\frac{dC_{Mcg}}{dC_L} = h - h_n$$

$$\frac{dC_{Mcg}}{dC_L} = -4\frac{d\alpha}{dC_L}$$

$$= -0.8$$

38.

A thin airfoil is mounted in a low-speed, subsonic wind tunnel, in which the Mach number is 0.1. At a point on the airfoil, the pressure coefficient is measured to be −1.2. If the flow velocity is increased such that the free-stream Mach number is 0.6, the pressure coefficient at the same point on the airfoil will approximately be:

(A) −3.5 (B) −2.9 (C) −1.5 (D) −0.75

Ans : (C)

$$C_{Pcompressible} = \frac{C_{Pincompressible}}{\sqrt{1-M_\infty^2}} = \frac{-1.2}{\sqrt{1-0.6^2}} = -1.5$$

39.

Assuming ISA standard sea level conditions (288.16 K, density of 1.225 kg/m^3, g = 9.81 m/s^2, R = 287 J/(kg-K)), the density (in kg/m^3) of air at Leh, which is at an altitude of 3500 m above mean sea level is _________ (accurate to two decimal places).

ANS: 0.86

$$T_2 = T_1 - \lambda h$$

$$T_2 = 288.16 - (0.0065) * (3500) = 265.41\ k$$

$$\frac{\rho_2}{\rho_1} = (\frac{T_2}{T_1})^{\frac{g}{\lambda R} - 1}.$$

$$\rho_2 = 0.86\ kg/m^3$$

40.

Air at 50 kPa pressure and 400 K temperature flows in a duct at Mach 3.0. A part of the flow leaks through an opening on the duct wall into the ambient, where the pressure is 30 kPa. The maximum Mach number achieved in the discharge is _______ (accurate to two decimal places). (Ratio of specific heats of air is $\gamma = 1.4$).

ANS: 3.35

41.

An axial compressor rotor with 50 % degree of reaction, operates with an axial velocity of 200 m/s. The absolute flow angle at the inlet of the rotor is 22° with reference to the axial direction. If the axial velocity is assumed to remain constant through the rotor, the magnitude of the relative velocity (in m/s) at the rotor exit is __________ (accurate to one decimal place).

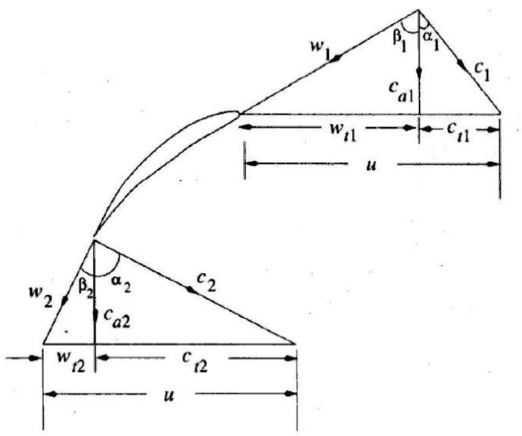
ANS: 215.7

R = 1/2

i.e. $\alpha_1 = \beta_2 = 22^0$

$C_a = 200\ m/s$

$$w_2 = \frac{200}{\cos 22} = 215.7\ m/s$$



42.

A thin-walled tube with external radius of 100 mm and wall thickness of 2 mm, is fixed at one end. It is subjected to a compressive force of 1 N acting at a point on the circumference parallel to its length. The maximum normal stress (in kPa) experienced by the structure is ______________ (accurate to two decimal places).

ANS: -2.39

M = 1 X 100 = 100 N.mm

$$I = \pi R^3 t$$

P = 1 N

$$A = 2\,\pi R t$$

$$\sigma_{max} = \sigma_{bending} + \sigma_{compression}$$

$$\sigma_{max} = \frac{My}{I} + \frac{P}{A}$$

$$\sigma_{max} = 0.002386\ MPa$$

$$\sigma_{max} = -2.39\ kPa$$ (compressive)

43.

A rocket has an initial mass of 150 kg. After operating for a duration of 10 s, its final mass is 50 kg. If the acceleration due to gravity is 9.81 m/s^2 and the thrust produced by the rocket is 19.62 kN, the specific impulse of the rocket is

(A) 400 s
(B) 300 s
(C) 200 s
(D) 100 s

ANS = (C)

$$\dot{m}_P = \frac{150 - 50}{10} = 10\ kg/s$$

F = $\dot{m}_P * C_j$

19620 = 10 * C_j

$$C_j = 1962\ m/s$$

$$I_{sp} = \frac{C_j}{g} = 200\ sec$$

44.

An aircraft with a gross weight of 2000 kg, has a speed of 130 m/s at sea level, where the conditions are: 1 atmosphere (pressure), 288 K (temperature), and 1.23 kg/m^3 (density). The speed (in m/s) required by the aircraft at an altitude of 9000 m, where the conditions are: 0.31 atmosphere, 230 K, and 0.47 kg/m^3, to maintain a steady, level flight is ________ (accurate to two decimal places).

Ans : 210.30

$$\sqrt{\sigma} = \sqrt{\frac{\rho_h}{\rho_{SL}}}$$

$$V_T = \frac{V_e}{\sqrt{\sigma}} = \frac{130}{\sqrt{\frac{0.47}{1.23}}} = 210.30 \text{ m/s}$$

45.

The components of stress in a body under plane stress condition, in the absence of body forces, is given by:

$\sigma_{xx} = Ax^2$; $\sigma_{yy} = 12x^2 - 6y^2$ and $\sigma_{xy} = 12xy$.

The coefficient, A, such that the body is under equilibrium is _____ (accurate to one decimal place).

Ans : - 6.0

$$\frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} + \frac{\partial \sigma_{xz}}{\partial z} + X = 0$$

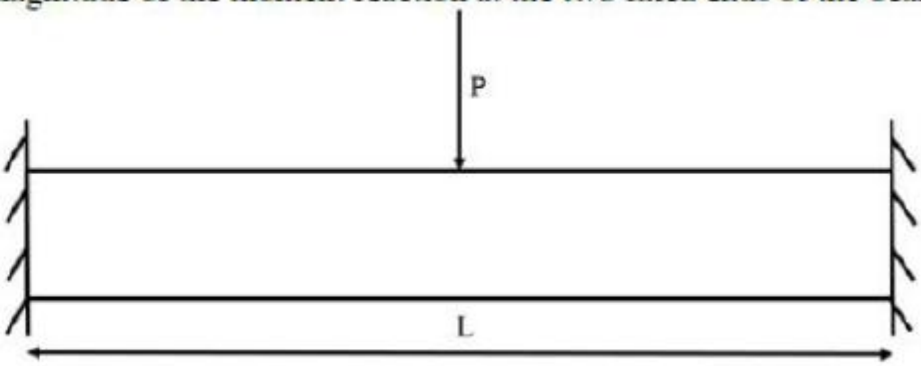
Body forces are zero,

$$2Ax + 12x = 0$$

$$\Rightarrow A = -6$$

46.

A clamped-clamped beam, subjected to a point load P at the midspan, is shown in the figure below. The magnitude of the moment reaction at the two fixed ends of the beam is



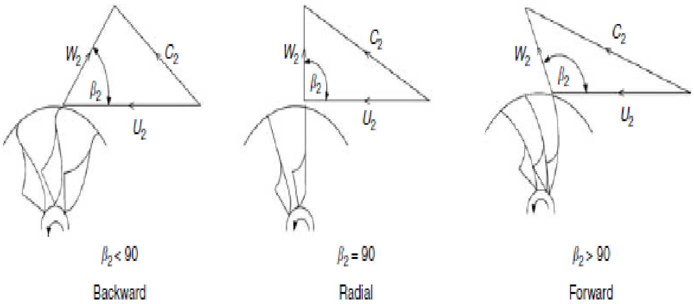
(A) PL/2 (B) PL/4 (C) PL/8 (D) PL/16

ANS: (C) Indeterminate beam, can be solved using Virtual work principle

47.

The relative velocity of air leaving a straight radial impeller of a centrifugal compressor is 100 m/s. If the impeller tip speed is 200 m/s, for a slip free operation, the absolute velocity (in m/s) at the impeller exit is __________ (accurate to one decimal place).

ANS: 223.6



$$C_2 = \sqrt{w_2^2 + u_2^2} = 223.6 \text{ m/s}$$

48.

The relation between pressure (p) and velocity (V) for a steady, isentropic flow at two points along a streamline is, (c is a constant)

(A) $c(p_2^{\gamma} - p_1^{\gamma}) = \frac{V_1^2}{2} - \frac{V_2^2}{2}$

(B) $c(p_2^{\frac{\gamma}{\gamma-1}} - p_1^{\frac{\gamma}{\gamma-1}}) = \frac{V_1^2}{2} - \frac{V_2^2}{2}$

(C) $c(p_2^{\frac{\gamma-1}{\gamma}} - p_1^{\frac{\gamma-1}{\gamma}}) = \frac{V_1^2}{2} - \frac{V_2^2}{2}$

(D) $c(p_2^{\gamma-1} - p_1^{\gamma-1}) = \frac{V_1^2}{2} - \frac{V_2^2}{2}$

ANS: (C)

$$h_{01} = h_{02}$$

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

$$h_2 - h_1 = \frac{V_1^2}{2} - \frac{V_2^2}{2}$$

$$C_P(T_2 - T_1) = \frac{V_1^2}{2} - \frac{V_2^2}{2}$$

$$C_P T_1[(\frac{p_2}{p_1})^{\frac{\gamma-1}{\gamma}} - 1] = \frac{V_1^2}{2} - \frac{V_2^2}{2}$$

$$C_P T_1 P_1^{\frac{\gamma-1}{\gamma}}[P_2^{\frac{\gamma-1}{\gamma}} - P_1^{\frac{\gamma-1}{\gamma}}] = \frac{V_1^2}{2} - \frac{V_2^2}{2}$$

$$c[P_2^{\frac{\gamma-1}{\gamma}} - P_1^{\frac{\gamma-1}{\gamma}}] = \frac{V_1^2}{2} - \frac{V_2^2}{2}$$

49.

The magnitude of the x-component of a unit vector at the point (1, 1) that is normal to equi-potential lines of the potential function $\phi(r) = \frac{1}{r^2+4}$, where $r = \sqrt{x^2+y^2}$, is ______ (accurate to two decimal places).

ANS: -0.71

Unit vector, $\hat{n} = \frac{\nabla\varphi}{|\nabla\varphi|}$

$$\nabla\varphi = \sum i \frac{\partial\varphi}{\partial x}$$

$$= \sum i \frac{-2r}{(r^2+4)^2} \cdot \frac{\partial r}{\partial x}$$

$$= \sum i \frac{-2x}{(r^2+4)^2}$$

$$\nabla\varphi = \frac{-2}{(r^2+4)^2}[x\hat{\imath} + y\hat{\jmath}]$$

$$\nabla\varphi = \frac{-1}{18}[\hat{\imath} + \hat{\jmath}]$$

$$|\nabla\varphi| = \frac{1}{18}\sqrt{1+1} = \frac{1}{9\sqrt{2}}$$

$$\hat{n} = \frac{\nabla\varphi}{|\nabla\varphi|} = -\frac{1}{\sqrt{2}}\hat{\imath} - \frac{1}{\sqrt{2}}\hat{\jmath}$$

Magnitude of x-component of unit vector = -0.71

50.

A solid circular shaft of diameter d is under pure torsion of magnitude T. The maximum tensile stress experienced at any point on the shaft is

(A) $\frac{32T}{\pi d^3}$ (B) $\frac{16T}{\pi d^4}$ (C) $\frac{32T}{\pi d^4}$ (D) $\frac{16T}{\pi d^3}$

ANS: (D)

$$\tau = \frac{T}{J} r$$

$$\tau = \frac{16T}{\pi d^3}$$

$$\sigma_{I,II} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_I = \frac{16T}{\pi d^3}$$

51.

An axial compressor that generates a stagnation pressure ratio of 4.0, operates with inlet and exit stagnation temperatures of 300 K and 480 K, respectively. If the ratio of specific heats (γ) is 1.4, the isentropic efficiency of the compressor is

(A) 0.94 (B) 0.81
(C) 0.72 (D) 0.63

ANS: (B)

$$r = \frac{P_{02}}{P_{01}} = 4$$

$$\eta_{ic} = \frac{T'_{02} - T_{01}}{T_{02} - T_{01}}$$

$$\eta_{ic} = \frac{T_{01}[r^{\frac{\gamma-1}{\gamma}} - 1]}{T_{02} - T_{01}} = 0.81$$

52.

An aircraft with mass of 400,000 kg cruises at 240 m/s at an altitude of 10 km. Its lift to drag ratio at cruise is 15. Assuming g as 9.81 m/s^2, the power (in MW) needed for it to cruise is ________ (accurate to two decimal places).

Ans : 62.78

m = 400,000 kg
v = 240 m/s
L/D = 15

$$P_{required} = D \times V$$

$$D = D \times \frac{L}{L}$$

$$= D \times \frac{W}{L}$$

$$= W \times \frac{D}{L}$$

$$\Rightarrow P_{required} = \frac{400000 \times 9.81}{15} \times 240 = 62.78 \text{ MW}$$

53.

A spacecraft forms a circular orbit at an altitude of 150 km above the surface of a spherical Earth. Assuming the gravitational parameter, $\mu = 3.986 \times 10^{14}\ m^3/s^2$ and radius of earth, R_E = 6,400 km, the velocity required for the injection of the spacecraft, parallel to the local horizon, is ______________ (accurate to two decimal places).

Ans : 7.80 km/s , 7800.96 m/s
[* The unit for velocity is not mentioned in the question]

V = $\sqrt{\frac{\mu}{r}} = \sqrt{\frac{\mu}{6400+150}}$ = 7.80 km/s = 7800.96 m/s

54.

Consider a cubical tank of side 2 m with its top open. It is filled with water up to a height of 1 m. Assuming the density of water to be 1000 kg/m^3, g as 9.81 m/s^2 and the atmospheric pressure to be 100 kPa, the net hydrostatic force (in kN) on the side face of the tank due to the air and water is ______ (accurate to two decimal places).

ANS: 209.81 kN

Atmospheric pressure at bottom = 100 KPa
Hydrostatic pressure due to water = ρgh=1000 x 9.81 x 1=9810 $N/m2$
Force on one side of wall will be area of pressure diagram multiplied with width of tank,

Force = (Area x width) for Atmospheric pressure + (Area x width) for hydrostatic pressure of water
F = {(100 X 10^3 * 1) * 2} + { ½ * 9810 * 1) * 2}
F = 209.81 kN

55.

A 1 m long massless cantilever beam oscillates at 2Hz, while a 60 kg mass is attached at the tip of it. The flexural rigidity of the beam (in kN-m^2) is ______________ (accurate to two decimal places).

Ans : 3.16

ω_n = 2 Hz

$$\delta = \frac{W\,l^3}{3\,E\,I} = x$$

$$F = k\,x$$

$$\Rightarrow k = \frac{3\,EI}{l^3}$$

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$\Rightarrow \{2\pi\ (2)\}^2 = \frac{3\,EI}{l^3} \times \frac{1}{m}$$

$$\Rightarrow EI = 3.15\ kN\text{-}m^2$$

GENERAL APTITUDE

56.

The perimeters of a circle, a square and an equilateral triangle are equal. Which one of the following statements is true?

(A) The circle has the largest area.
(B) The square has the largest area.
(C) The equilateral triangle has the largest area.
(D) All the three shapes have the same area.

Ans : (A)

$$P_C = P_S = P_T$$

$$\pi D = 4a = 3s$$

$$\text{Area of circle} = \frac{\pi}{4} D^2 \qquad (\pi D = 4a)$$

$$\text{Area of square} = a^2$$

$$= \frac{\pi^2 D^2}{16}$$

$$\text{Area of triangle} = \frac{\sqrt{3}}{4} s^2$$

$$= \frac{\sqrt{3}}{4}\left(\frac{\pi D}{3}\right)^2 \qquad (\pi D = 3s)$$

$$= \frac{\sqrt{3}}{36}(\pi D)^2$$

Therefore,

$$\frac{\pi}{4} > \frac{\pi^2}{16} > \frac{\sqrt{3}}{36}\pi^2$$

Hence, circle has the largest area.

57.

Find the missing group of letters in the following series:
BC, FGH, LMNO, _____

(A) UVWXY (B) TUVWX (C) STUVW (D) RSTUV

Ans : (B)
BC, FGH, LMNO,TUVWX

58.

"The dress _________ her so well that they all immediately _________ her on her appearance."

The words that best fill the blanks in the above sentence are

(A) complemented, complemented (B) complimented, complemented
(C) complimented, complimented (D) complemented, complimented

Ans : (D)
Complemented means – complete / to improve something or emphasize their qualities
Complimented means – remark of admiration/ to praise someone

59.

The value of the expression $\frac{1}{1+\log_u vw} + \frac{1}{1+\log_v wu} + \frac{1}{1+\log_w uv}$ is _________.

(A) -1 (B) 0 (C) 1 (D) 3

Ans: (C)

$$\frac{1}{1+\log_u vw} + \frac{1}{1+\log_v wu} + \frac{1}{1+\log_w uv}$$

$$= \frac{1}{\log_u u + \log_u vw} + \frac{1}{\log_v v + \log_v wu} + \frac{1}{\log_w w + \log_w uv}$$

$$= \frac{1}{\log_u uvw} + \frac{1}{\log_v uvw} + \frac{1}{\log_w uvw}$$

$$= \log_{uvw} u + \log_{uvw} v + \log_{uvw} w$$

$$= \log_{uvw} uvw = 1$$

60.

"The judge's standing in the legal community, though shaken by false allegations of wrongdoing, remained _________."

The word that best fills the blank in the above sentence is

(A) undiminished (B) damaged (C) illegal (D) uncertain

Ans : (A)

Undiminished – unambitious / unskilled
Undiminished means – not diminished, reduced or lessened.

61.

A wire would enclose an area of 1936 m^2, if it is bent into a square. The wire is cut into two pieces. The longer piece is thrice as long as the shorter piece. The long and the short pieces are bent into a square and a circle, respectively. Which of the following choices is closest to the sum of the areas enclosed by the two pieces in square meters?

(A) 1096 (B) 1111 (C) 1243 (D) 2486

Ans : (C)

Initial square area = 1936 m^2; a = 44m
Length of wire = 4a = 4 x 44 = 176 m

Now, part-1 length = 3 x 44 = 132 m
Part-2 length = 1 x 44 = 44 m

Long wire is bent in square, so
4a = 132, i.e. a = 33 m

Area of square = 33^2 = 1089 m^2
Now, small wire is bent in circle, So, circle perimeter , $\pi D = 44$
Hence, D = 14 m

Area of circle = $\frac{\pi}{4} D^2$
= 153.94 m^2

Total area enclosed = Area of square + area of circle
= 1059 + 153.94
= 1242.97
= 1243 m^2

62.

An unbiased coin is tossed six times in a row and four different such trials are conducted. One trial implies six tosses of the coin. If H stands for head and T stands for tail, the following are the observations from the four trials:
(1) HTHTHT (2) TTHHHT (3) HTTHHT (4) HHHT__ __.

Which statement describing the last two coin tosses of the fourth trial has the highest probability of being correct?

(A) Two T will occur.
(B) One H and one T will occur.
(C) Two H will occur.
(D) One H will be followed by one T.

Ans : (B)

For remaining last two tosses possible cases are:
H H
H T
T H
T T

Out of 4 possible cases one H and T will have the highest probability of occurrence.

63.

A contract is to be completed in 52 days and 125 identical robots were employed, each operational for 7 hours a day. After 39 days, five-seventh of the work was completed. How many additional robots would be required to complete the work on time, if each robot is now operational for 8 hours a day?

(A) 50 (B) 89 (C) 146 (D) 175

Ans: [This question is to be verified]

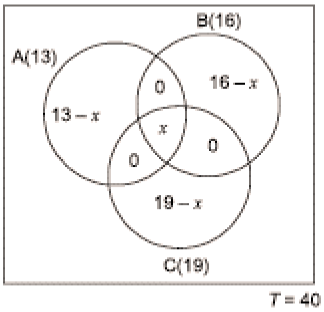
$125 \times 7 \times 39 = \frac{5}{7}$ W
W = 47775 robot hours
Left work = 47775 – (125 x 7 x 39)
= 13650 robot hours
$13 * x * 8 = 13560$
$x = 131.25$
Addition robot required = 131.25 – 125 = 6.25 = 7

64.

Forty students watched films A, B and C over a week. Each student watched either only one film or all three. Thirteen students watched film A, sixteen students watched film B and nineteen students watched film C. How many students watched all three films?

(A) 0 (B) 2 (C) 4 (D) 8

Ans : (C)



Total students = 40
13 – x + 16 – x + 19 – x + x = 40
Number of students who watched all three movies(x) = 4

65.

A house has a number which needs to be identified. The following three statements are given that can help in identifying the house number.

i. If the house number is a multiple of 3, then it is a number from 50 to 59.
ii. If the house number is NOT a multiple of 4, then it is a number from 60 to 69.
iii. If the house number is NOT a multiple of 6, then it is a number from 70 to 79.

What is the house number?

(A) 54 (B) 65 (C) 66 (D) 76

Ans : (D)

From condition i, possible numbers are : 51, 54, 57
From condition ii, possible numbers are : 61, 62, 63, 65, 66, 67, 69
From condition iii, possible numbers are : 70, 71, 73, 74, 75, 76, 77, 79

⇒ 54 is multiple of 3 and 6. But, it is not the multiple of 4. So, according to second condition, it cannot be the answer
⇒ 65 is not multiple of 6.So, according to third condition, it cannot be the answer
⇒ 66 is multiple of 3 and it does not belong to 50 to 59. So it will not be the answer
⇒ For 76 all the conditions are satisfied. So, it is the answer.