Q. 1 – Q. 25 carry one mark each.

Q.1 While minimizing the function $f(x)$, necessary and sufficient conditions for a point, x_0 to be a minima are:

(A) $f'(x_0) > 0$ and $f''(x_0) = 0$
(B) $f'(x_0) < 0$ and $f''(x_0) = 0$
(C) $f'(x_0) = 0$ and $f''(x_0) < 0$
(D) $f'(x_0) = 0$ and $f''(x_0) > 0$

Q.2 In Newton-Raphson iterative method, the initial guess value (x_{ini}) is considered as zero while finding the roots of the equation: $f(x) = -2 + 6x - 4x^2 + 0.5x^3$. The correction, Δx, to be added to x_{ini} in the first iteration is ________________.

Q.3 Given, $i = \sqrt{-1}$, the value of the definite integral, I = $\int_0^{\pi/2} \frac{\cos x + i \sin x}{\cos x - i \sin x} dx$ is:

(A) 1
(B) -1
(C) i
(D) $-i$

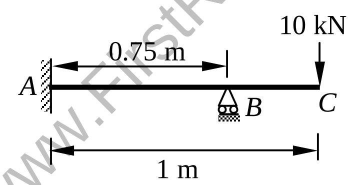
Q.4 $\lim_{x \to \infty} \left(1 + \frac{1}{x}\right)^{2x}$ is equal to

(A) e^{-2}
(B) e
(C) 1
(D) e^2

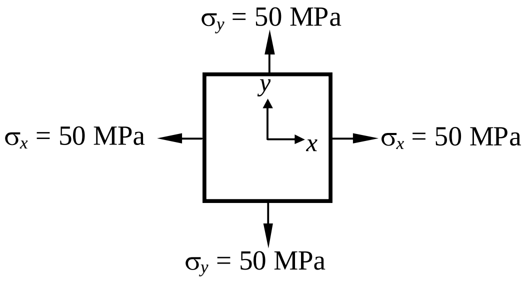
Q.5 Let $\mathbf{A} = [a_{ij}]$, $1 \le i, j \le n$ with $n \ge 3$ and $a_{ij} = i.j$. The rank of **A** is:

(A) 0
(B) 1
(C) n–1
(D) n

Q.6 A horizontal beam *ABC* is loaded as shown in the figure below. The distance of the point of contraflexure from end *A* (in m) is ___________________.

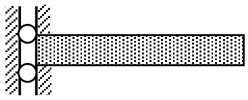


Q.7 For the plane stress situation shown in the figure, the maximum shear stress and the plane on which it acts are:



(A) –50 MPa, on a plane 45^0 clockwise *w.r.t.* *x*-axis
(B) –50 MPa, on a plane 45^0 anti-clockwise *w.r.t.* *x*-axis
(C) 50 MPa, at all orientations
(D) Zero, at all orientations

Q.8 A guided support as shown in the figure below is represented by three springs (horizontal, vertical and rotational) with stiffness k_x, k_y and k_θ respectively. The limiting values of k_x, k_y and k_θ are:



(A) ∞, 0, ∞ (B) ∞, ∞, ∞ (C) 0, ∞, ∞ (D) ∞, ∞, 0

Q.9 A column of size 450 mm × 600 mm has unsupported length of 3.0 m and is braced against side sway in both directions. According to IS 456: 2000, the minimum eccentricities (in mm) with respect to major and minor principal axes are:

(A) 20.0 and 20.0 (B) 26.0 and 21.0 (C) 26.0 and 20.0 (D) 21.0 and 15.0

Q.10 Prying forces are:

(A) shearing forces on the bolts because of the joints
(B) tensile forces due to the flexibility of connected parts
(C) bending forces on the bolts because of the joints
(D) forces due the friction between connected parts

Q.11 A steel member '*M*' has reversal of stress due to live loads, whereas another member '*N*' has reversal of stress due to wind load. As per IS 800: 2007, the maximum slenderness ratio permitted is:

(A) less for member '*M*' than that of member '*N*'
(B) more for member '*M*' than for member '*N*'
(C) same for both the members
(D) not specified in the Code

Q.12 If the water content of a fully saturated soil mass is 100%, the void ratio of the sample is:

(A) less than specific gravity of soil
(B) equal to specific gravity of soil
(C) greater than specific gravity of soil
(D) independent of specific gravity of soil

Q.13 In friction circle method of slope stability analysis, if r defines the radius of the slip circle, the radius of friction circle is:

(A) $r \sin\phi$ (B) r (C) $r \cos\phi$ (D) $r \tan\phi$

Q.14 Net ultimate bearing capacity of a footing embedded in a clay stratum

(A) increases with depth of footing only
(B) increases with size of footing only
(C) increases with depth and size of footing
(D) is independent of depth and size of footing

Q.15 Surcharge loading required to be placed on the horizontal backfill of a smooth retaining vertical wall so as to completely eliminate tensile crack is:

(A) $2\,c$ (B) $2\,c\,k_a$ (C) $2c\sqrt{k_a}$ (D) $2c/\sqrt{k_a}$

Q.16 The relationship between the length scale ratio (L_r) and the velocity scale ratio (V_r) in hydraulic models, in which Froude dynamic similarity is maintained, is:

(A) $V_r = L_r$ (B) $L_r = \sqrt{V_r}$ (C) $V_r = L_r^{1.5}$ (D) $V_r = \sqrt{L_r}$

Q.17 A nozzle is so shaped that the average flow velocity changes linearly from 1.5 m/s at the beginning to 15 m/s at its end in a distance of 0.375 m. The magnitude of the convective acceleration (in m/s^2) at the end of the nozzle is ___________.

Q.18 A hydraulic jump takes place in a frictionless rectangular channel. The pre-jump depth is y_p. The alternate and sequent depths corresponding to y_p are y_a and y_s respectively. The correct relationship among y_p , y_a and y_s is:

(A) $y_a < y_s < y_p$
(B) $y_p < y_s < y_a$
(C) $y_p < y_s = y_a$
(D) $y_p = y_s = y_a$

Q.19 The relationship between porosity (η), specific yield (S_y) and specific retention (S_r) of an unconfined aquifer is:

(A) $S_y + S_r = \eta$
(B) $S_y + \eta = S_r$
(C) $S_r + \eta = S_y$
(D) $S_y + S_r + \eta = 1$

Q.20 A groundwater sample was found to contain 500 mg/L total dissolved solids (TDS). TDS (in %) present in the sample is ____________.

Q.21 SO_2 and CO adversely affect

(A) oxygen carrying capacity of blood and functioning of lungs respectively
(B) functioning of the respiratory system and brain respectively
(C) functioning of the respiratory system and oxygen carrying capacity of blood respectively
(D) functioning of air passages and chest respectively

Q.22 A superspeedway in New Delhi has among the highest super-elevation rates of any track on the Indian Grand Prix circuit. The track requires drivers to negotiate turns with a radius of 335 m and 33° banking. Given this information, the coefficient of side friction required in order to allow a vehicle to travel at 320 km/h along the curve is:

(A) 1.761 (B) 0.176 (C) 0.253 (D) 2.530

Q.23 The following statements are made related to the lengths of turning lanes at signalised intersections:

(i) 1.5 times the average number of vehicles (by vehicle type) that would store in turning lane per cycle during the peak hour
(ii) 2 times the average number of vehicles (by vehicle type) that would store in turning lane per cycle during the peak hour
(iii) Average number of vehicles (by vehicle type) that would store in the adjacent through lane per cycle during the peak hour
(iv) Average number of vehicles (by vehicle type) that would store in all lanes per cycle during the peak hour

As per the IRC recommendations, the correct choice for design length of storage lanes is:

(A) Maximum of (ii and iii)
(B) Maximum of (i and iii)
(C) Average of (i and iii)
(D) Only (iv)

Q.24 In a leveling work, sum of the Back Sight (B.S.) and Fore Sight (F.S.) have been found to be 3.085 m and 5.645 m respectively. If the Reduced Level (R.L.) of the starting station is 100.000 m, the R.L. (in m) of the last station is ___________.

Q.25 The combined correction due to curvature and refraction (in m) for a distance of 1 km on the surface of Earth is:

(A) 0.0673 (B) 0.673 (C) 7.63 (D) 0.763

Q. 26 – Q. 55 carry two marks each.

Q.26 The probability density function of a random variable, x is

$$f(x) = \frac{x}{4}\left(4 - x^2\right) \quad \text{for} \quad 0 \le x \le 2$$
$$= 0 \quad \text{otherwise}$$

The mean, μ_x of the random variable is _______________.

Q.27 Consider the following second order linear differential equation

$$\frac{d^2y}{dx^2} = -12x^2 + 24x - 20$$

The boundary conditions are: at x = 0, y = 5 and at x = 2, y = 21

The value of y at x = 1 is ____________.

Q.28 The two Eigen values of the matrix $\begin{bmatrix} 2 & 1 \\ 1 & p \end{bmatrix}$ have a ratio of 3:1 for p = 2. What is another value of p for which the Eigen values have the same ratio of 3:1?

(A) -2 (B) 1 (C) 7/3 (D) 14/3

Q.29 For step-size, Δx =0.4, the value of following integral using Simpson's 1/3 rule is _____________.

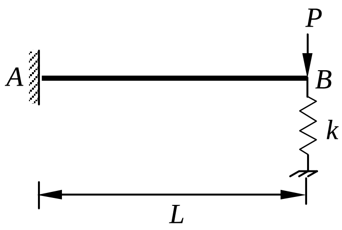
$$\int_0^{0.8} \left(0.2 + 25x - 200x^2 + 675x^3 - 900x^4 + 400x^5\right) dx$$

Q.30 In a system, two connected rigid bars AC and BC are of identical length, L with pin supports at A and B. The bars are interconnected at C by a frictionless hinge. The rotation of the hinge is restrained by a rotational spring of stiffness, k. The system initially assumes a straight line configuration, ACB. Assuming both the bars as weightless, the rotation at supports, A and B, due to a transverse load, P applied at C is:

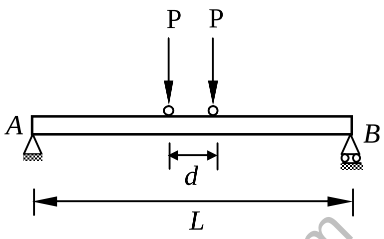
(A) $\frac{PL}{4k}$ (B) $\frac{PL}{2k}$ (C) $\frac{P}{4k}$ (D) $\frac{Pk}{4L}$

Q.31 A simply supported reinforced concrete beam of length 10 m sags while undergoing shrinkage. Assuming a uniform curvature of 0.004 m^{-1} along the span, the maximum deflection (in m) of the beam at mid-span is ______________.

Q.32 A steel strip of length, L = 200 mm is fixed at end A and rests at B on a vertical spring of stiffness, k = 2 N/mm. The steel strip is 5 mm wide and 10 mm thick. A vertical load, P = 50 N is applied at B, as shown in the figure. Considering E = 200 GPa, the force (in N) developed in the spring is __________.

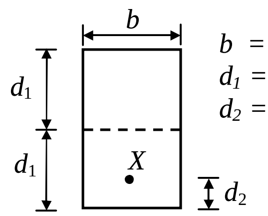


Q.33 A simply supported beam AB of span, L = 24 m is subjected to two wheel loads acting at a distance, d = 5 m apart as shown in the figure below. Each wheel transmits a load, P = 3 kN and may occupy any position along the beam. If the beam is an I-section having section modulus, S = 16.2 cm^3, the maximum bending stress (in GPa) due to the wheel loads is ________________________.



Q.34 According to the concept of Limit State Design as per IS 456: 2000, the probability of failure of a structure is _____________.

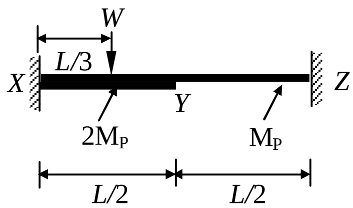
Q.35 In a pre-stressed concrete beam section shown in the figure, the net loss is 10% and the final pre-stressing force applied at X is 750 kN. The initial fiber stresses (in N/mm^2) at the top and bottom of the beam were:



b = 250 mm
d_1 = 200 mm
d_2 = 100 mm

(A) 4.166 and 20.833
(B) –4.166 and –20.833
(C) 4.166 and –20.833
(D) –4.166 and 20.833

Q.36 A fixed end beam is subjected to a load, W at 1/3rd span from the left support as shown in the figure. The collapse load of the beam is:

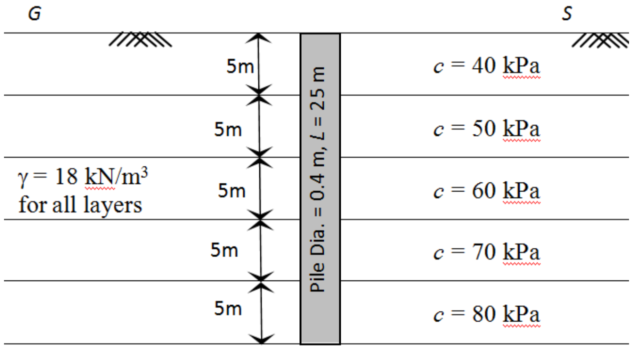


(A) 16.5 M_P/L
(B) 15.5 M_P/L
(C) 15.0 M_P/L
(D) 16.0 M_P/L

Q.37 A 588 cm^3 volume of moist sand weighs 1010 gm. Its dry weight is 918 gm and specific gravity of solids, G is 2.67. Assuming density of water as 1 gm/cm^3, the void ratio is ___________.

Q.38 A 4 m thick layer of normally consolidated clay has an average void ratio of 1.30. Its compression index is 0.6 and coefficient of consolidation is 1 m^2/yr. If the increase in vertical pressure due to foundation load on the clay layer is equal to the existing effective overburden pressure, the change in the thickness of the clay layer is _______________ mm

Q.39 A pile of diameter 0.4 m is fully embedded in a clay stratum having 5 layers, each 5 m thick as shown in the figure below. Assume a constant unit weight of soil as 18 kN/m^3 for all the layers. Using λ-method (λ = 0.15 for 25 m embedment length) and neglecting the end bearing component, the ultimate pile capacity (in kN) is ________________.



Q.40 Stress path equation for tri-axial test upon application of deviatoric stress is, $q = 10\sqrt{3} + 0.5\,p$. The respective values of cohesion, c (in kPa) and angle of internal friction, ϕ are:

(A) 20 and 20°
(B) 20 and 30°
(C) 30 and 30°
(D) 30 and 20°

Q.41 A 6 m high retaining wall having a smooth vertical back face retains a layered horizontal backfill. Top 3 m thick layer of the backfill is sand having an angle of internal friction, ϕ = 30° while the bottom layer is 3 m thick clay with cohesion, c = 20 kPa. Assume unit weight for both sand and clay as 18 kN/m^3. The total active earth pressure per unit length of the wall (in kN/m) is:

(A) 150
(B) 216
(C) 156
(D) 196

Q.42 A field channel has cultivable commanded area of 2000 hectares. The intensities of irrigation for gram and wheat are 30% and 50% respectively. Gram has a kor period of 18 days, kor depth of 12 cm, while wheat has a kor period of 18 days and a kor depth of 15 cm. The discharge (in m^3/s) required in the field channel to supply water to the commanded area during the kor period is ________________.

Q.43 A triangular gate with a base width of 2 m and a height of 1.5 m lies in a vertical plane. The top vertex of the gate is 1.5 m below the surface of a tank which contains oil of specific gravity 0.8. Considering the density of water and acceleration due to gravity to be 1000 kg/m^3 and 9.81 m/s^2 respectively, the hydrostatic force (in kN) exerted by the oil on the gate is __________________.

Q.44 The velocity components of a two dimensional plane motion of a fluid are: $u = \frac{y^3}{3} + 2x - x^2 y$ and $v = xy^2 - 2y - \frac{x^3}{3}$.

The correct statement is:

(A) Fluid is incompressible and flow is irrotational
(B) Fluid is incompressible and flow is rotational
(C) Fluid is compressible and flow is irrotational
(D) Fluid is compressible and flow is rotational

Q.45 The average surface area of a reservoir in the month of June is 20 km^2. In the same month, the average rate of inflow is 10 m^3/s, outflow rate is 15 m^3/s, monthly rainfall is 10 cm, monthly seepage loss is 1.8 cm and the storage change is 16 million m^3. The evaporation (in cm) in that month is:

(A) 46.8 (B) 136.0 (C) 13.6 (D) 23.4

Q.46 A pipe of 0.7 m diameter has a length of 6 km and connects two reservoirs A and B. The water level in reservoir A is at an elevation 30 m above the water level in reservoir B. Halfway along the pipe line, there is a branch through which water can be supplied to a third reservoir C. The friction factor of the pipe is 0.024. The quantity of water discharged into reservoir C is 0.15 m^3/s. Considering the acceleration due to gravity as 9.81 m/s^2 and neglecting minor losses, the discharge (in m^3/s) into the reservoir B is _______________.

Q.47 A landfill is to be designed to serve a population of 200000 for a period of 25 years. The solid waste (SW) generation is 2 kg/person/day. The density of the un-compacted SW is 100 kg/m^3 and a compaction ratio of 4 is suggested. The ratio of compacted fill (i.e., SW + cover) to compacted SW is 1.5. The landfill volume (in million m^3) required is ____________.

Q.48 A water treatment plant of capacity, 1 m^3/s has filter boxes of dimensions 6 m × 10 m. Loading rate to the filters is 120 m^3/day/m^2. When two of the filters are out of service for back washing, the loading rate (in m^3/day/m^2) is _______________.

Q.49 Ultimate BOD of a river water sample is 20 mg/L. BOD rate constant (natural log) is 0.15 day^{-1}. The respective values of BOD (in %) exerted and remaining after 7 days are:

(A) 45 and 55 (B) 55 and 45
(C) 65 and 35 (D) 75 and 25

Q.50 In a wastewater treatment plant, primary sedimentation tank (PST) designed at an overflow rate of 32.5 m^3/day/m^2 is 32.5 m long , 8.0 m wide and liquid depth of 2.25 m. If the length of the weir is 75 m, the weir loading rate (in m^3/day/m) is _______________.

Q.51 The relation between speed *u* (in km/h) and density *k* (number of vehicles / km) for a traffic stream on a road is *u* = 70 – 0.7*k*. The capacity on this road is ________________ vph (vehicles/hour).

Q.52 Match the information related to tests on aggregates given in Group-I with that in Group-II.

Group-I	Group-II
P. Resistance to impact	1. Hardness
Q. Resistance to wear	2. Strength
R. Resistance to weathering action	3. Toughness
S. Resistance to crushing	4. Soundness

(A) P-1, Q-3, R-4, S-2
(B) P-3, Q-1, R-4, S-2
(C) P-4, Q-1, R-3, S-2
(D) P-3, Q-4, R-2, S-1

Q.53 In Marshall method of mix design, the coarse aggregate, fine aggregate, fines and bitumen having respective values of specific gravity 2.60, 2.70, 2.65 and 1.01, are mixed in the relative proportions (% by weight) of 55.0, 35.8, 3.7 and 5.5 respectively. The theoretical specific gravity of the mix and the effective specific gravity of the aggregates in the mix respectively are:

(A) 2.42 and 2.63
(B) 2.42 and 2.78
(C) 2.42 and 2.93
(D) 2.64 and 2.78

Q.54 The bearings of two inaccessible stations, S_1 (Easting 500 m, Northing 500 m) and S_2 (Easting 600 m, Northing 450 m) from a station S_3 were observed as 225^0 and $153^0\ 26'$ respectively. The independent Easting (in m) of station S_3 is:

(A) 450.000
(B) 570.710
(C) 550.000
(D) 650.000

Q.55 Two Pegs A and B were fixed on opposite banks of a 50 m wide river. The level was set up at A and the staff readings on Pegs A and B were observed as 1.350 m and 1.550 m, respectively. Thereafter the instrument was shifted and set up at B. The staff readings on Pegs B and A were observed as 0.750 m and 0.550 m, respectively. If the R.L. of Peg A is 100.200 m, the R.L. (in m) of Peg B is ___________________.

END OF THE QUESTION PAPER