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GATE 2020 CIVIL ENGINEERING GUIDE

with **10 Practice Sets**

(6 in Book & 4 Online Sets)

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PREFACE

With an aim to provide the best possible material to the students to prepare for the GATE, GATE Masterpiece is a one of its kind for the preparation of Civil Engineering Exams and a result of many years of research. Another unique feature of this book is that it has Numerical Answer Type Questions which have been added by the IITs.

The key idea, which allows this book to deal with a wide range of content related to the Civil Engineering Exams along with covering each and every topic, is based on the current syllabus introduced by IIT for GATE Exam. Covering 100% topics of the syllabus for Civil Engineering Exams, the content of this book includes an extended version of a collection of exhaustive theory, past year questions, practice problems and Mock Tests. It also covers 'Simple MCQs,' 'Linked Answer type MCQs' and 'Common Data based MCQs' questions in great numbers.

In writing this book, we have assumed that readers are well acquainted with the very basic concepts of Structural, Geotechnical, Water Resources, Environmental, Traffic, etc. Drafted in compliance with GATE syllabus by qualified and experienced professionals, this book has questions of previous 15 years of GATE examinations. Having 100-150 questions in each unit with detailed solutions, this book in helpful in practicing and preparing for the exams in an effective manner within the shortest span of time.

Structured approach, Introduction of Concepts in Simple Terms, Fundamental Principles in Context of Simple Application and Accuracy were our main objectives that we aimed while writing this book. In order to make sure that the students get well prepared for the exams, we have divided into three sections.

Students who read this book will gain a basic understanding of principles, problems and solutions, including an introduction to the format of GATE exam.

1. General Aptitude - Covering Verbal Ability and Numerical Ability
2. Engineering Mathematics
3. Technical Section

SUPPLEMENTS: Online Tests which contains 4 Mock Tests designed exactly on the latest pattern of GATE exam.

ACKNOWLEDGEMENT

Special thanks go to our team which has given its best possible effort to prepare such a book, thoroughly checked the solutions, so as to eliminate any possibility of error.

However, some errors may have crept in, so feedbacks from the readers regarding the same are highly appreciated.

Author

Syllabus for Civil Engineering (CE)

SECTION I : GENERAL APTITUDE(GA)

Verbal Ability:
English grammar, sentence completion, verbal analogies, word groups, instructions, critical reasoning and verbal deduction.

Numerical Ability:
Numerical computation, numerical estimation, numerical reasoning and data interpretation.

SECTION II : ENGINEERING MATHEMATICS

Linear Algebra:
Matrix algebra; Systems of linear equations; Eigen values and Eigen vectors. Calculus: Functions of single variable; Limit, continuity and differentiability; Mean value theorems, local maxima and minima, Taylor and Maclaurin series; Evaluation of definite and indefinite integrals, application of definite integral to obtain area and volume; Partial derivatives; Total derivative; Gradient, Divergence and Curl, Vector identities, Directional derivatives, Line, Surface and Volume integrals, Stokes, Gauss and Green's theorems.

Ordinary Differential Equation (ODE):
First order (linear and non-linear) equations; higher order linear equations with constant coefficients; Euler-Cauchy equations; Laplace transform and its application in solving linear ODEs; initial and boundary value problems.

Partial Differential Equation (PDE):
Fourier series; separation of variables; solutions of onedimensional diffusion equation; first and second order one-dimensional wave equation and two-dimensional Laplace equation.

Probability and Statistics:
Definitions of probability and sampling theorems; Conditional probability; Discrete Random variables: Poisson and Binomial distributions; Continuous random variables: normal and exponential distributions; Descriptive statistics - Mean, median, mode and standard deviation; Hypothesis testing.

Numerical Methods:
Accuracy and precision; error analysis. Numerical solutions of linear and non-linear algebraic equations; Least square approximation, Newton's and Lagrange polynomials, numerical differentiation, Integration by trapezoidal and Simpson's rule, single and multi-step methods for first order differential equations.

SECTION III : TECHNICAL SECTION

UNIT I : STRUCTURAL ENGINEERING

Engineering Mechanics:
System of forces, free-body diagrams, equilibrium equations; Internal forces in structures; Friction and its applications; Kinematics of point mass and rigid body; Centre of mass; Euler's equations of motion; Impulse-momentum; Energy methods; Principles of virtual work..

Solid Mechanics:
Bending moment and shear force in statically determinate beams; Simple stress and strain relationships; Theories of failures; Simple bending theory, flexural and shear stresses, shear centre; Uniform torsion, buckling of column, combined and direct bending stresses.

Structural Analysis:
Statically determinate and indeterminate structures by force/energy methods; Method of superposition; Analysis of trusses, arches, beams, cables and frames; Displacement methods: Slope deflection and moment distribution methods; Influence lines; Stiffness and flexibility methods of structural analysis.

Construction Materials and Management:
Construction Materials: Structural steel - composition, material properties and behaviour; Concrete - constituents, mix design, short-term and long-term properties; Bricks and mortar; Timber; Bitumen.

Construction Management:
Types of construction projects; Tendering and construction contracts; Rate analysis and standard specifications; Cost estimation; Project planning and network analysis - PERT and CPM.

Concrete Structures:
Working stress, Limit state and Ultimate load design concepts; Design of beams, slabs, columns; Bond and development length; Prestressed concrete; Analysis of beam sections at transfer and service loads.

Steel Structures:
Working stress and Limit state design concepts; Design of tension and compression members, beams and beam- columns, column bases; Connections - simple and eccentric, beam-column connections, plate girders and trusses; Plastic analysis of beams and frames.

UNIT II : GEOTECHNICAL ENGINEERING

Soil Mechanics:
Origin of soils, soil structure and fabric; Three-phase system and phase relationships, index properties; Unified and Indian standard soil classification system; Permeability - one dimensional flow, Darcy's law; Seepage through soils - two-dimensional flow, flow nets, uplift pressure, piping; Principle of effective stress, capillarity, seepage force and quicksand condition; Compaction in laboratory and field conditions; Onedimensional consolidation, time rate of consolidation; Mohr's circle, stress paths, effective and total shear strength parameters, characteristics of clays and sand.

Foundation Engineering:

Sub-surface investigations - scope, drilling bore holes, sampling, plate load test, standard penetration and cone penetration tests; Earth pressure theories - Rankine and Coulomb; Stability of slopes - finite and infinite slopes, method of slices and Bishop's method; Stress distribution in soils - Boussinesq's and Westergaard's theories, pressure bulbs; Shallow foundations - Terzaghi's and Meyerhoff's bearing capacity theories, effect of water table; Combined footing and raft foundation; Contact pressure; Settlement analysis in sands and clays; Deep foundations - types of piles, dynamic and static formulae, load capacity of piles in sands and clays, pile load test, negative skin friction.

UNIT III : WATER RESOURCES ENGINEERING

Fluid Mechanics:

Properties of fluids, fluid statics; Continuity, momentum, energy and corresponding equations; Potential flow, applications of momentum and energy equations; Laminar and turbulent flow; Flow in pipes, pipe networks; Concept of boundary layer and its growth.

Hydraulics:

Forces on immersed bodies; Flow measurement in channels and pipes; Dimensional analysis and hydraulic similitude; Kinematics of flow, velocity triangles; Basics of hydraulic machines, specific speed of pumps and turbines; Channel Hydraulics - Energy-depth relationships, specific energy, critical flow, slope profile, hydraulic jump, uniform flow and gradually varied flow

Hydrology:

Hydrologic cycle, precipitation, evaporation, evapo-transpiration, watershed, infiltration, unit hydrographs, hydrograph analysis, flood estimation and routing, reservoir capacity, reservoir and channel routing, surface run-off models, ground water hydrology - steady state well hydraulics and aquifers; Application of Darcy's law.

Irrigation:

Duty, delta, estimation of evapo-transpiration; Crop water requirements; Design of lined and unlined canals, head works, gravity dams and spillways; Design of weirs on permeable foundation; Types of irrigation systems, irrigation methods; Water logging and drainage; Canal regulatory works, cross-drainage structures, outlets and escapes.

UNIT IV : ENVIRONMENTAL ENGINEERING

Water and Waste Water:

Quality standards, basic unit processes and operations for water treatment. Drinking water standards, water requirements, basic unit operations and unit processes for surface water treatment, distribution of water. Sewage and sewerage treatment, quantity and characteristics of wastewater. Primary, secondary and tertiary treatment of wastewater, effluent discharge standards. Domestic wastewater treatment, quantity of characteristics of domestic wastewater, primary and secondary treatment. Unit operations and unit processes of domestic wastewater, sludge disposal.

Air Pollution:

Types of pollutants, their sources and impacts, air pollution meteorology, air pollution control, air quality standards and limits.

Municipal Solid Wastes:

Characteristics, generation, collection and transportation of solid wastes, engineered systems for solid waste management (reuse/ recycle, energy recovery, treatment and disposal).

Noise Pollution:

Impacts of noise, permissible limits of noise pollution, measurement of noise and control of noise pollution.

UNIT V : TRANSPORTATION ENGINEERING

Transportation Infrastructure:

Highway alignment and engineering surveys; Geometric design of highways - cross-sectional elements, sight distances, horizontal and vertical alignments; Geometric design of railway track; Airport runway length, taxiway and exit taxiway design.

Highway Pavements:

Highway materials - desirable properties and quality control tests; Design of bituminous paving mixes; Design factors for flexible and rigid pavements; Design of flexible pavement using IRC: 37-2012; Design of rigid pavements using IRC: 58-2011; Distresses in concrete pavements.

Traffic Engineering:

Traffic studies on flow, speed, travel time - delay and O-D study, PCU, peak hour factor, parking study, accident study and analysis, statistical analysis of traffic data; Microscopic and macroscopic parameters of traffic flow, fundamental relationships; Control devices, signal design by Webster's method; Types of intersections and channelization; Highway capacity and level of service of rural highways and urban roads.

UNIT VI : SURVEYING

Geomatics Engineering:

Principles of surveying; Errors and their adjustment; Maps - scale, coordinate system; Distance and angle measurement - Levelling and trigonometric levelling; Traversing and triangulation survey; Total station; Horizontal and vertical curves. Photogrammetry - scale, flying height; Remote sensing - basics, platform and sensors, visual image interpretation; Basics of Geographical information system (GIS) and Geographical Positioning system (GPS).

TOPIC WISE NUMBER OF QUESTIONS ANALYSIS

GATE Papers (Civil Engineering)

Subject	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
General Aptitude						5	5	10	10	10	10	10	10	10
Engg Mathematics	9	11	11	9	9	8	8	8	9	9	10	10	12	7
TECHNICAL SECTION														
Mechanics	11	8	2	5	4	1	2	4	3	5	4	3	5	4
Structural Analysis	3	5	3	1	2	4	4	5	2	2	2	2	4	3
Concrete Structures	6	6	7	4	3	7	6	5	5	3	5	5	2	3
Steel Structures	3	3	3	4	2	1	2	5	5	5	2	3	1	3
Geotechnical Engineering	13	13	14	10	11	10	10	14	12	9	10	13	6	11
Fluid Mechanics and Hydraulics	10	9	8	4	5	1	5	9	4	5	7	4	5	5
Hydrology & Irrigation	4	6	6	4	3	8	5	5	2	3	3	4	5	5
Environmental Engineering	9	9	8	8	6	7	6	8	5	6	5	5	9	6
Transportation Engineering	9	10	12	4	5	6	6	8	3	4	5	5	3	4
Surveying	5	5	3	2	2	2	1	5	5	4	2	1	3	4

GATE CIVIL ENGINEERING SOLVED PAPER

2019 Set-1

Duration: 3 hrs **Maximum Marks: 100**

INSTRUCTIONS

1. There are a total of 65 questions carrying 100 marks.
2. The subject specific GATE paper section consists of 55 questions. The GA section consists of 10 questions.
3. Questions are of Multiple Choice Question (MCQ) or Numerical Answer type. A multiple choice question will have four choices for the answer with only one correct choice. For numerical answer type questions, the answer is a number and no choices will be given.
4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions will result in NEGATIVE marks. For all 1 mark questions, $\frac{1}{3}$ mark will be deducted for each wrong answer. For all 2 marks questions, $\frac{2}{3}$ mark will be deducted for each wrong answer.
5. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE.**

GENERAL APTITUDE TEST

QUESTIONS 1 TO 5 CARRY ONE MARK EACH

1. The lecture was attended by quite __________ students, so the hall was not very __________.

(a) a few, quite (b) few, quiet
(c) a few, quiet (d) few, quite

2. They have come a long way in __________ trust among the users.

(a) creating (b) created
(c) creation (d) create

3. On a horizontal ground, the base of a straight ladder is 6 m away from the base of a vertical pole. The ladder makes an angle of 45° to the horizontal. If the ladder is resting at a point located at one-fifth of the height of the pole from the bottom, the height of the pole is __________ meters.

(a) 15 (b) 25
(c) 30 (d) 35

4. If E = 10; J = 20; O = 30; and T = 40, what will be P + E + S + T?

(a) 51 (b) 82
(c) 120 (d) 164

5. The CEO's decision to quit was as shocking to the Board as it was to __________.

(a) I (b) me
(c) my (d) myself

QUESTIONS 6 TO 10 CARRY TWO MARKS EACH

6. The new cotton technology, Bollgard-II. with herbicide tolerant traits has developed into a thriving business in India. However, the commercial use of this technology is not legal in India. Not withstanding that, reports indicate that the herbicide tolerant Bt cotton had been purchased by farmers at an average of Rs 200 more than the control price of ordinary cotton, and planted in 15% of the cotton growing area in the 2017 Kharif season.

Which one of the following statements can be inferred from the given passage?

(a) Farmers want to access the new technology if India benefits from it
(b) Farmers want to access the new technology even if it is not legal
(c) Farmers want to access the new technology for experimental purposes
(d) Farmers want to access the new technology by paying high price

7. In a sports academy of 300 people, 105 play only cricket, 70 play only hockey, 50 play only football, 25 play both cricket and hockey, 15 play both hockey and football and 30 play both cricket and football. The rest of them play all three sports. What is the percentage of people who play at least two sports?

(a) 23.30 (b) 25.00

(c) 28.00 (d) 50.00

8. "The increasing interest in tribal characters might be a mere coincidence, but the timing is of interest. None of this, though, is to say that the tribal hero has arrived in Hindi cinema, or that the new crop of characters represents the acceptance of the tribal character in the industry. The films and characters are too few to be described as a pattern."

What does the word 'arrived' mean in the paragraph above?

(a) reached a terminus

(b) came to a conclusion

(c) attained a status

(d) went to a place

9. A square has sides 5 cm smaller than the sides of a second square. The area of the larger square is four times the area of the smaller square. The side of the larger square is __________ cm.

(a) 18.50 (b) 15.10

(c) 10.00 (d) 8.50

10. P, Q, R, S and T are related and belong to the same family. P is the brother of S. Q is the wife of P. R and T are the children of the siblings P and S respectively. Which one of the following statements is necessarily FALSE?

(a) S is the aunt of R

(b) S is the aunt of T

(c) S is the sister-in-law of Q

(d) S is the brother of P

TECHNICAL SECTION TEST

QUESTIONS 1 TO 25 CARRY ONE MARK EACH

1. Which one of the following is correct?

(a) $\lim_{x\to 0}\left(\dfrac{\sin 4x}{\sin 2x}\right)=2$ and $\lim_{x\to 0}\left(\dfrac{\tan x}{x}\right)=1$

(b) $\lim_{x\to 0}\left(\dfrac{\sin 4x}{\sin 2x}\right)=1$ and $\lim_{x\to 0}\left(\dfrac{\tan x}{x}\right)=1$

(c) $\lim_{x\to 0}\left(\dfrac{\sin 4x}{\sin 2x}\right)=\infty$ and $\lim_{x\to 0}\left(\dfrac{\tan x}{x}\right)=1$

(d) $\lim_{x\to 0}\left(\dfrac{\sin 4x}{\sin 2x}\right)=2$ and $\lim_{x\to 0}\left(\dfrac{\tan x}{x}\right)=\infty$

2. Consider a two-dimensional flow through isotropic soil along x direction and z direction. If h is the hydraulic head, the Laplace's equation of continuity is expressed as

(a) $\dfrac{\partial h}{\partial x}+\dfrac{\partial h}{\partial z}=0$ (b) $\dfrac{\partial h}{\partial x}+\dfrac{\partial h}{\partial x}\dfrac{\partial h}{\partial z}+\dfrac{\partial h}{\partial z}=0$

(c) $\dfrac{\partial^2 h}{\partial x^2}+\dfrac{\partial^2 h}{\partial z^2}=0$ (d) $\dfrac{\partial^2 h}{\partial x^2}+\dfrac{\partial^2 h}{\partial x\,\partial z}+\dfrac{\partial^2 h}{\partial z^2}=0$

3. A simple mass-spring oscillatory system consists of a mass m, suspended from a spring of stiffness k. Considering z as the displacement of the system at any time t, the equation of motion for the free vibration of the system is $m\ddot{z}+kz=0$. The natural frequency of the system is

(a) $\dfrac{k}{m}$ (b) $\sqrt{\dfrac{k}{m}}$

(c) $\dfrac{m}{k}$ (d) $\sqrt{\dfrac{m}{k}}$

4. For a small value of h, the Taylor series expansion for $f(x + h)$ is

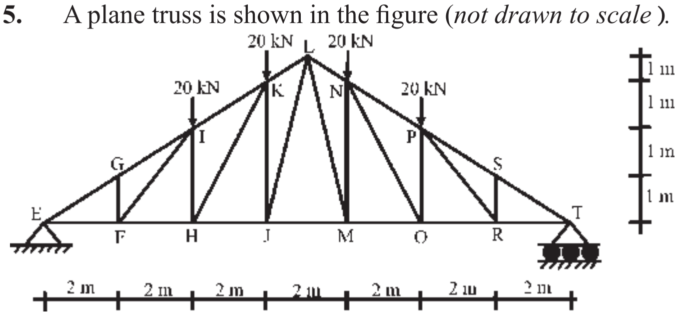
(a) $f(x)+hf'(x)+\dfrac{h^2}{2!}f''(x)+\dfrac{h^3}{3!}f'''(x)+\ldots\infty$

(b) $f(x)-hf'(x)+\dfrac{h^2}{2!}f''(x)+\dfrac{h^3}{3!}f'''(x)+\ldots\infty$

(c) $f(x)+hf'(x)+\dfrac{h^2}{2}f''(x)+\dfrac{h^3}{3}f'''(x)+\ldots\infty$

(d) $f(x)-hf'(x)+\dfrac{h^2}{2}f''(x)-\dfrac{h^3}{3}f'''(x)+\ldots\infty$

5. A plane truss is shown in the figure (*not drawn to scale*).



Which one of the options contains ONLY zero force members in the truss?

(a) FG, FI, HI, RS (b) FG, FH, HI, RS

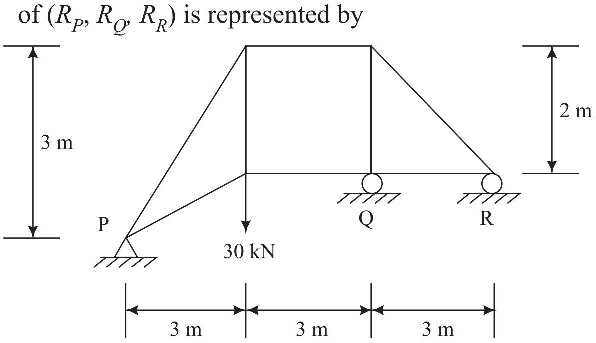
(c) FI, HI, PR, RS (d) FI, FG, RS, PR

6. An element is subjected to biaxial normal tensile strains of 0.0030 and 0.0020. The normal strain in the plane of maximum shear strain is

(a) Zero (b) 0.0010

(c) 0.0025 (d) 0.0050

7. Consider the pin-jointed plane truss shown in the figure (*not drawn to scale*). Let R_P, R_Q, and R_R denote the vertical reactions (upward positive) applied by the supports at P, Q, and R, respectively, on the truss. The correct combination of (R_P, R_Q, R_R) is represented by



(a) (30, –30, 30) kN (b) (20, 0, 10) kN

(c) (10, 30, –10) kN (d) (0, 60, –30) kN

8. Assuming that there is no possibility of shear buckling in the web, the maximum reduction permitted by IS 800-2007 in the (low-shear) design bending strength of a semi-compact steel section due to high shear is

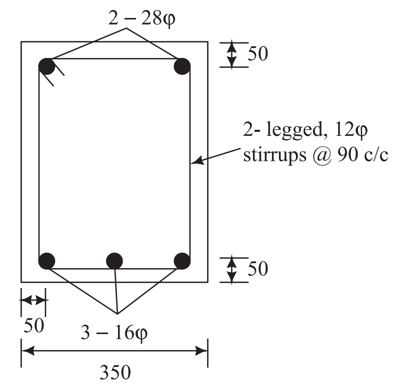
(a) zero

(b) 25%

(c) 50%

(d) governed by the area of the flange

9. In the reinforced beam section shown in the figure (*not drawn to scale*), the nominal cover provided at the bottom of the beam as per IS 456-2000, is



All dimensions are in mm

(a) 30 mm (b) 36 mm

(c) 42 mm (d) 50 mm

10. The interior angles of four triangles are given below:

Triangle	Interior Angles
P	85°, 50°, 45°
Q	100°, 55°, 25°
R	100°, 45°, 35°
S	130°, 30°, 20°

Which of the triangles are ill-conditioned and should be avoided in Triangulation surveys?

(a) Both P and R (b) Both Q and R

(c) Both P and S (d) Both Q and S

11. The coefficient of average rolling friction of a road is f_r and its grade is +G%. If the grade of this road is doubled, what will be the percentage change in the braking distance (for the design vehicle to come to a stop) measured along the horizontal (assume all other parameters are kept unchanged)?

(a) $\frac{0.01G}{f_r + 0.02G} \times 100$ (b) $\frac{f_r}{f_r + 0.02G} \times 100$

(c) $\frac{0.02G}{f_r + 0.01G} \times 100$ (d) $\frac{2f_r}{f_r + 0.01G} \times 100$

12. An isolated concrete pavement slab of length L is resting on a frictionless base. The temperature of the top and bottom fibre of the slab are T_t and T_b, respectively. Given: the coefficient of thermal expansion = α and the elastic modulus = E. Assuming $T_t > T_b$ and the unit weight of concrete as zero, the maximum thermal stress is calculated as

(a) $L\alpha(T_t - T_b)$ (b) $E\alpha(T_t - T_b)$

(c) $\frac{E\alpha(T_t - T_b)}{2}$ (d) zero

13. In a rectangular channel, the ratio of the velocity head to the flow depth for critical flow condition, is

(a) $\frac{1}{2}$ (b) $\frac{2}{3}$

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

14. If the path of an irrigation canal is below the bed level of a natural stream, the type of cross-drainage structure provided is

(a) Aqueduct (b) Level crossing

(c) Sluice gate (d) Super passage

15. A catchment may be idealised as a rectangle. There are three rain gauges located inside the catchment at arbitrary locations. The average precipitation over the catchment is estimated by two methods: (i) Arithmetic mean (P_A), and (ii) Thiessen polygon (P_T). Which one of the following statements is correct?

(a) P_A is always smaller than P_T

(b) P_A is always greater than P_T

(c) P_A is always equal to P_T

(d) There is no definite relationship between P_A and P_T

16. A retaining wall of height H with smooth vertical backface supports a backfill inclined at an angle β with the horizontal. The backfill consists of cohesionless soil having angle of internal friction ϕ. If the active lateral thrust acting on the wall is P_a, which one of the following statements is TRUE?

(a) P_a acts at a height $H/2$ from the base of the wall and at an angle β with the horizontal

(b) P_a acts at a height $H/2$ from the base of the wall and at an angle ϕ with the horizontal

(c) P_a acts at a height $H/3$ from the base of the wall and at an angle β with the horizontal

(d) P_a acts at a height $H/3$ from the base of the wall and at an angle ϕ with the horizontal

17. In a soil specimen, the total stress, effective stress, hydraulic gradient and critical hydraulic gradient are σ, σ', i and i_c, respectively. For initiation of quicksand condition, which one of the following statements is TRUE?

(a) $\sigma' \neq 0$ and $i = i_c$

(b) $\sigma' = 0$ and $i = i_c$

(c) $\sigma' \neq 0$ and $i \neq i_c$

(d) $\sigma = 0$ and $i = i_c$

18. Which one of the following is a secondary pollutant?

(a) Ozone

(b) Carbon Monoxide

(c) Hydrocarbon

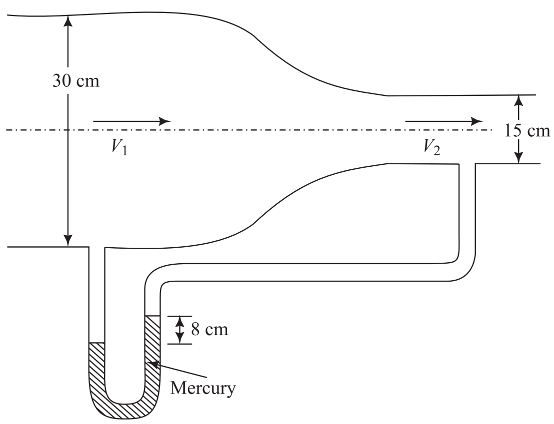
(d) Volatile Organic Carbon (VOC)

19. For a given loading on a rectangular plain concrete beam with an overall depth of 500 *mm,* the compressive strain and tensile strain developed at the extreme fibers are of the same magnitude of 2.5×10^{-4}. The curvature in the beam cross-section (in m^{-1}, *round off to 3 decimal places*), is __________

20. A completely mixed dilute suspension of sand particles having diameters 0.25, 0.35, 0.40, 0.45 and 0.50 *mm* are filled in a transparent glass column of diameter 10 *cm* and height 2.50 *m*. The suspension is allowed to settle without any disturbance. It is observed that all particles of diameter 0.35 *mm* settle to the bottom of the column in 30 *s*. For the same period of 30 *s*, the percentage removal (*round off to integer value*) of particles of diameters 0.45 and 0.50 *mm* from the suspension is __________

21. The maximum number of vehicles observed in any five minute period during the peak hour is 160. If the total flow in the peak hour is 1000 vehicles, the five minute peak hour factor *(round off to 2 decimal places)* is __________

22. A circular duct carrying water gradually contracts from a diameter of 30 *cm* to 15 *cm*. The figure *(not drawn to scale)* shows the arrangement of differential manometer attached to the duct.



When the water flows, the differential manometer shows a deflection of 8 *cm* of mercury (*Hg*). The values of specific gravity of mercury and water are 13.6 and 1.0, respectively. Consider the acceleration due to gravity, $g = 9.81\ m/s^2$. Assuming frictionless flow, the flow rate (in m^3/s, *round off to* 3 *decimal places*) through the duct is __________

23. The probability that the annual maximum flood discharge will exceed 25000 m^3/s, at least once in next 5 years is found to be 0.25. The return period of this flood event (in *years, round off to 1 decimal place*) is __________

24. A soil has specific gravity of its solids equal to 2.65. The mass density of water is 1000 kg/m^3. Considering zero air voids and 10% moisture content of the soil sample, the dry density (in kg/m^3, *round off to 1 decimal place*) would be __________

25. A concentrated load of 500 *kN* is applied on an elastic half space. The ratio of the increase in vertical normal stress at depths of 2 *m* and 4 *m* along the point of the loading, as per Boussinesq's theory, would be __________

QUESTIONS 26 TO 55 CARRY TWO MARKS EACH

26. Which one of the following is NOT a correct statement?

(a) The function $\sqrt[x]{x}$, $(x > 0)$, has the global maxima at $x' = e$

(b) The function $\sqrt[x]{x}$, $(x > 0)$, has the global minima at $x = e$

(c) The function x^3 has neither global minima nor global maxima

(d) The function $|x|$ has the global minima at $x = 0$

27. A one-dimensional domain is discretized into N sub-domains of width Δx with node numbers $i = 0, 1, 2, 3, ..., N$. If the time scale is discretized in steps of Δt, the forward-time and centered-space finite difference approximation at i^{th} node and n^{th} time step, for the partial differential equation $\frac{\partial v}{\partial t} = \beta \frac{\partial^2 v}{\partial x^2}$ is

(a) $\frac{v_i^{(n+1)} - v_i^{(n)}}{\Delta t} = \beta \left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{(\Delta x)^2} \right]$

(b) $\frac{v_{i+1}^{(n+1)} - v_i^{(n)}}{\Delta t} = \beta \left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{2\Delta x} \right]$

(c) $\frac{v_i^{(n)} - v_i^{(n-1)}}{\Delta t} = \beta \left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{(\Delta x)^2} \right]$

(d) $\frac{v_i^{(n)} - v_i^{(n-1)}}{2\Delta t} = \beta \left[\frac{v_{i+1}^{(n)} - 2v_i^{(n)} + v_{i-1}^{(n)}}{2\Delta x} \right]$

28. A rectangular open channel has a width of 5 *m* and a bed slope of 0.001. For a uniform flow of depth 2 *m*, the velocity is 2 *m/s*. The Manning's roughness coefficient for the channel is

(a) 0.002 (b) 0.017
(c) 0.033 (d) 0.050

29. For the following statements:

P - The lateral stress in the soil while being tested in an oedometer is always at-rest.

Q - For a perfectly rigid strip footing at deeper depths in a sand deposit, the vertical normal contact stress at the footing edge is greater than that at its centre.

R - The corrections for overburden pressure and dilatancy are not applied to measured SPT-N values in case of clay deposits.

The correct combination of the statements is

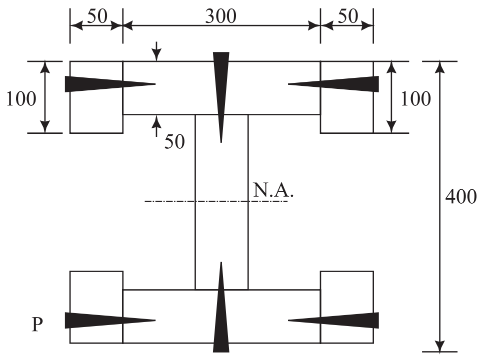
(a) P – TRUE; Q – TRUE; R – TRUE
(b) P – FALSE; Q – FALSE; R – TRUE
(c) P – TRUE; Q – TRUE; R – FALSE
(d) P – FALSE; Q – FALSE; R – FALSE

30. Consider two functions: $x = \psi \ln \phi$ and $y = \phi \ln \psi$. Which one of the following is the correct expression for $\frac{\partial \psi}{\partial x}$?

(a) $\frac{x \ln \psi}{\ln \phi \ln \psi - 1}$ (b) $\frac{x \ln \phi}{\ln \phi \ln \psi - 1}$

(c) $\frac{\ln \phi}{\ln \phi \ln \psi - 1}$ (d) $\frac{\ln \psi}{\ln \phi \ln \psi - 1}$

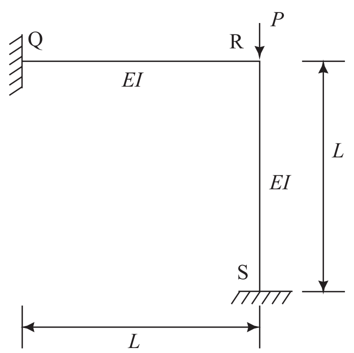
31. The cross-section of a built-up wooden beam as shown in the figure (*not drawn to scale*) is subjected to a vertical shear force of 8 *kN*. The beam is symmetrical about the neutral axis (N.A.) shown, and the moment of inertia about N.A. is 1.5×10^9 mm^4. Considering that the nails at the location P are spaced longitudinally (along the length of the beam) at 60 *mm*, each of the nails at P will be subjected to the shear force of



All dimensions are in *mm*

(a) 60 *N* (b) 120 *N*
(c) 240 *N* (d) 480 *N*

32. The rigid-jointed plane frame QRS shown in the figure is subjected to a load *P* at the joint R. Let the axial deformations in the frame be neglected. If the support S undergoes a settlement of $\Delta = \frac{PL}{EI}$, the vertical reaction at the support S will become zero when β is equal to



(a) 0.1 (b) 3.0
(c) 7.5 (d) 48.0

33. If the section shown in the figure turns from fully-elastic to fully-plastic, the depth of neutral axis (N.A.), $\bar{y}$, decreases by

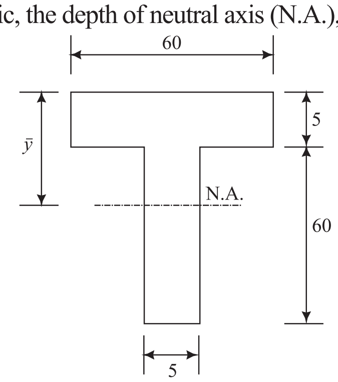


Figure no to scale
All dimensions are in *mm*

(a) 10.75 mm (b) 12.25 mm
(c) 13.75 mm (d) 15.25 mm

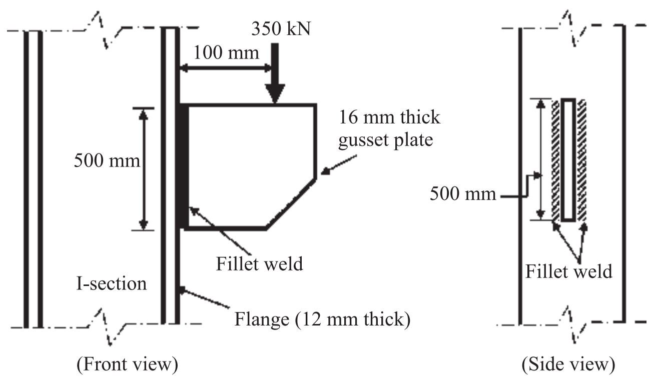
34. Sedimentation basin in a water treatment plant is designed for a flow rate of 0.2 m^3/s. The basin is rectangular with a length of 32 *m*, width of 8 *m*, and depth of 4 *m*. Assume that the settling velocity of these particles is governed by the Stokes' law. Given: density of the particles = 2.5 g/cm^3; density of water = 1 g/cm^3; dynamic viscosity of water = 0.01 *g*/(*cm.s*); gravitational acceleration = 980 cm/s^2. If the incoming water contains particles of diameter 25 μm (spherical and uniform), the removal efficiency of these particles is

(a) 51% (b) 65%
(c) 78% (d) 100%

35. A survey line was measured to be 285.5 *m* with a tape having a nominal length of 30 *m*. On checking, the true length of the tape was found to be 0.05 *m* too short. If the line lay on a slope of 1 in 10, the reduced length (horizontal length) of the line for plotting of survey work would be

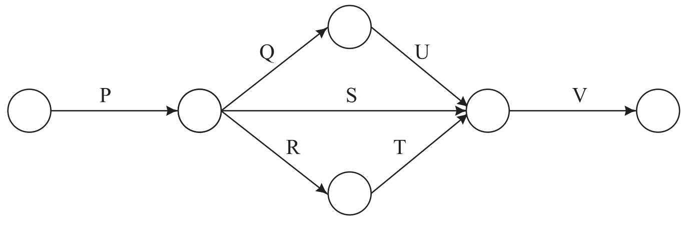
(a) 283.6 *m* (b) 284.5 *m*
(c) 285.0 *m* (d) 285.6 *m*

36. A 16 *mm* thick gusset plate is connected to the 12 *mm* thick flange plate of an I-section using fillet welds on both sides as shown in the figure (*not drawn to scale*). The gusset plate is subjected to a point load of 350 *kN* acting at a distance of 100 *mm* from the flange plate. Size of fillet weld is 10 *mm*.



The maximum resultant stress (in *MPa*, *round off to 1 decimal place*) on the fillet weld along the vertical plane would be __________

37. The network of a small construction project awarded to a contractor is shown in the following figure. The normal duration, crash duration, normal cost, and crash cost of all the activities are shown in the table. The indirect cost incurred by the contractor is *INR* 5000 per day.

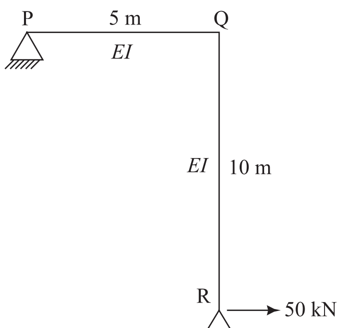


Activity	Normal Duration (*days*)	Crash Duration (*days*)	Normal Cost (*INR*)	Crash Cost (*INR*)
P	6	4	15000	25000
Q	5	2	6000	12000
R	5	3	8000	9500
S	6	3	7000	10000
T	3	2	6000	9000
U	2	1	4000	6000
V	4	2	20000	28000

If the project is targeted for completion in 16 days, the total cost (in *INR*) to be incurred by the contractor would be

38. A box measuring 50 *cm* × 50 *cm* × 50 *cm* is filled to the top with dry coarse aggregate of mass 187.5 *kg*. The water absorption and specific gravity of the aggregate are 0.5% and 2.5, respectively. The maximum quantity of water (in *kg, round off to 2 decimal places*) required to fill the box completely is __________

39. A portal frame shown in figure (*not drawn to scale*) has a hinge support at joint P and a roller support at joint R. A point load of 50 *kN* is acting at joint R in the horizontal direction. The flexural rigidity, *EI*, of each member is 10^6 kNm^2. Under the applied load, the horizontal displacement (in *mm*, *round off to 1 decimal place*) of joint R would be __________



40. A sample of air analysed at 0°C and 1 *atm* pressure is reported to contain 0.02 *ppm* (parts per million) of NO_2. Assume the gram molecular mass of NO_2 as 46 and its volume at 0°C and 1 *atm* pressure as 22.4 *litres per mole.* The equivalent NO_2 concentration (in *microgram per cubic meter*, *round off to 2 decimal places*) would be __________

41. A 0.80 *m* deep bed of sand filter (length 4 *m* and width 3 *m)* is made of uniform particles (diameter = 0.40 *mm,* specific gravity = 2.65, shape factor = 0.85) with bed porosity of 0.4. The bed has to be backwashed at a flow rate of 3.60 m^3/min. During backwashing, if the terminal settling velocity of sand particles is 0.05 *m/s*, the expanded bed depth (in *m, round off to 2 decimal places*) is __________

42. A wastewater is to be disinfected with 35 *mg/L* of chlorine to obtain 99% kill of micro-organisms. The number of micro-organisms remaining alive (N_t) at time *t,* is modelled by $N_t = N_o e^{-kt}$, where N_o is number of micro-organisms at $t = 0$, and *k* is the rate of kill. The wastewater flow rate is 36 m^3/h, and $k = 0.23$ min^{-1}. If the depth and width of the chlorination tank are 1.5 *m* and 1.0 *m,* respectively, the length of the tank (in *m, round off to 2 decimal places*) is __________

43. A staff is placed on a benchmark (BM) of reduced level (RL) 100.000 *m* and a the odolite is placed at a horizontal distance of 50 *m* from the BM to measure the vertical angles. The measured vertical angles from the horizontal at the staff readings of 0.400 *m* and 2.400 *m* are found to be the same. Taking the height of the instrument as 1.400 *m*, the RL (in *m*) of the theodolite station is __________

44. Consider the ordinary differential equation $x^2 \dfrac{d^2y}{dx^2} - 2x\dfrac{dy}{dx} + 2y = 0$. Given the values of $y(1) = 0$ and $y(2) = 2$, the value of $y(3)$ (round off to 1 decimal place), is __________

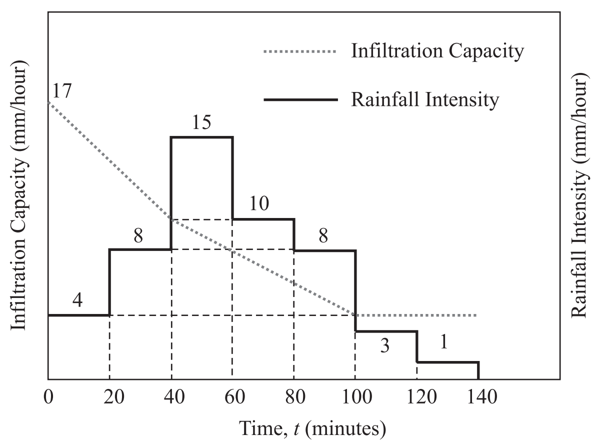
45. Average free flow speed and the jam density observed on a road stretch are 60 *km/h* and 120 *vehicles/km*, respectively. For a linear speed-density relationship, the maximum flow on the road stretch (in *vehicles/h*) is __________

46. Traffic on a highway is moving at a rate of 360 *vehicles per hour* at a location. If the number of vehicles arriving on this highway follows Poisson distribution, the probability (*round off to 2 decimal places*) that the headway between successive vehicles lies between 6 and 10 *seconds* is __________

47. A parabolic vertical curve is being designed to join a road of grade +5% with a road of grade –3%. The length of the vertical curve is 400 *m* measured along the horizontal. The vertical point of curvature (VPC) is located on the road of grade +5%. The difference in height between VPC and vertical point of intersection (VPI) (in *m, round off to the nearest integer*) is __________

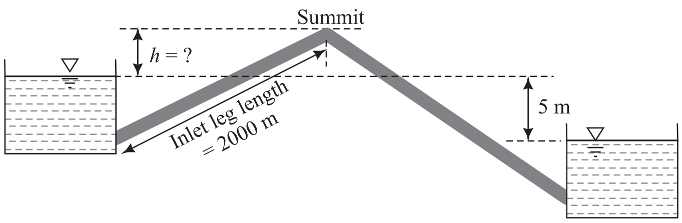
48. Tie bars of 12 *mm* diameter are to be provided in a concrete pavement slab. The working tensile stress of the tie bars is 230 *MPa*, the average bond strength between a tie bar and concrete is 2 *MPa*, and the joint gap between the slabs is 10 *mm.* Ignoring the loss of bond and the tolerance factor, the design length of the tie bars (in *mm, round off to the nearest integer)* is __________

49. The hyetograph of a storm event of duration 140 *minutes* is shown in the figure.



The infiltration capacity at the start of this event ($t = 0$) is 17 *mm/hour*, which linearly decreases to 10 *mm/hour* after 40 *minutes* duration. As the event progresses, the infiltration rate further drops down linearly to attain a value of 4 *mm/hour* at t = 100 *minutes* and remains constant thereafter till the end of the storm event. The value of the infiltration index, φ (in *mm/hour, round off to 2 decimal places*), is __________

50. Two water reservoirs are connected by a siphon (running full) of total length 5000 *m* and diameter of 0.10 *m,* as shown below (*figure not drawn to scale*).



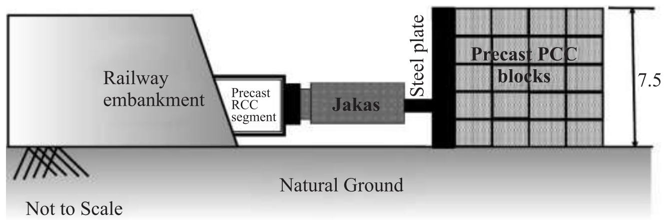
The inlet leg length of the siphon to its summit is 2000 *m.* The difference in the water surface levels of the two reservoirs is 5 *m.* Assume the permissible minimum absolute pressure at the summit of siphon to be 2.5 *m* of water when running full. Given: friction factor f = 0.02 throughout, atmospheric pressure = 10.3 *m* of water, and acceleration due to gravity $g = 9.81\ m/s^2$. Considering only major loss using Darcy-Weisbach equation, the maximum height of the summit of siphon from the water level of upper reservoir, h (in *m, round off to 1 decimal place*) is __________

51. Consider a laminar flow in the x-direction between two infinite parallel plates (Couette flow). The lower plate is stationary and the upper plate is moving with a velocity of 1 *cm/s* in the x-direction. The distance between the plates is 5 *mm* and the dynamic viscosity of the fluid is 0.01 $N\text{-}s/m^2$. If the shear stress on the lower plate is zero, the pressure gradient, $\frac{\partial p}{\partial x}$, (in N/m^2 *per m, round off to 1 decimal place*) is ________

52. A reinforced concrete circular pile of 12 *m* length and 0.6 *m* diameter is embedded in stiff clay which has an undrained unit cohesion of 110 kN/m^2. The adhesion factor is 0.5. The Net Ultimate Pullout (uplift) Load for the pile (in *kN*, *round off to 1 decimal place*) is __________

53. A granular soil has a saturated unit weight of 20 kN/m^3 and an effective angle of shearing resistance of 30°. The unit weight of water is 9.81 kN/m^3. A slope is to be made on this soil deposit in which the seepage occurs parallel to the slope up to the free surface. Under this seepage condition for a factor of safety of 1.5, the safe slope angle (in *degree*, *round off to 1 decimal place*) would be __________

54. A 3 *m* × 3 *m* square precast reinforced concrete segments to be installed by pushing them through an existing railway embankment for making an underpass as shown in the figure. A reaction arrangement using precast PCC blocks placed on the ground is to be made for the jacks.



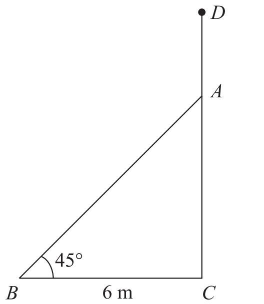
At each stage, the jacks are required to apply a force of 1875 *kN* to push the segment. The jacks will react against the rigid steel plate placed against the reaction arrangement. The footprint area of reaction arrangement on natural ground is 37.5 m^2. The unit weight of PCC block is 24 kN/m^3. The properties of the natural ground are: c = 17 *kPa*; ϕ = 25° and γ = 18 kN/m^3. Assuming that the reaction arrangement has rough interface and has the same properties that of soil, the factor of safety (*round off to 1 decimal place*) against shear failure is __________

55. A square footing of 4 *m* side is placed at 1 *m* depth in a sand deposit. The dry unit weight (γ) of sand is 15 kN/m^3. This footing has an ultimate bearing capacity of 600 *kPa.* Consider the depth factors: $d_q = d_\gamma$ = 1.0 and the bearing capacity factor: N_γ = 18.75. This footing is placed at a depth of 2 *m* in the same soil deposit. For a factor of safety of 3.0 as per Terzaghi's theory, the safe bearing capacity (in *kPa*) of this footing would be __________

HINTS & SOLUTIONS

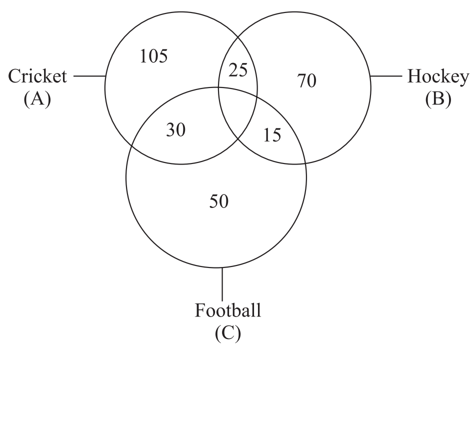
GENERAL APTITUDE TEST

1. **(c)** 'Quite a few' is a phrase. So, we will consider only option (A) and (C). The second blank will take 'quiet', meaning 'making little noise' while, 'quite', meaning 'intimately, absolutely, etc' is ruled out.
2. **(a)** The sentence requires a present participle. So, option (A) i.e., 'creating' will be the correct answer.
3. **(c)**



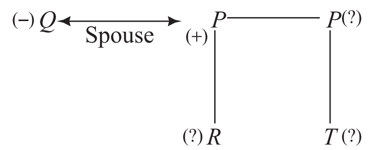
Let CD be a vertical pole and AB is a ladder.
$\angle ABC = 45°$
from ΔABC,
$\tan 45° = \frac{AC}{BC} \Rightarrow 1 = \frac{AC}{6}$
$\therefore \quad AC = 6$ cm
$ATQ, \quad AC = \frac{CD}{5}$
$\therefore \quad CD = 5 \times AC = 5 \times 6 = 30$ cm

4. **(c)** $E = 10 = 5 \times 2$, Here 5 is E's position in English alphabet.
$J = 20 = 10 \times 2$, Here 10 is J's position in English alphabet.
$O = 30 = 15 \times 2$, Here 15 is O's position in English alphabet.
$T = 40 = 20 \times 2$, Here 20 is T's position in English alphabet.
Now, $\quad P + E + S + T = 2 \times 16 + 2 \times 5 + 2 \times 19 + 2 \times 20$
$= 120$
5. **(b)** The blank needs a pronoun in 'objective case' as it follows the preposition 'to'. 'I' is subjective case; 'my' is an adjective that precedes any noun; 'myself' is used when action verb reflects on the subject 'I'; 'me' is objective case of 'I'. So, option (B) is the correct answer.
6. **(b)**
7. **(b)**



Here $\quad n(A \cup B \cup C) = 300$.
Let number of people who play all the three games are n.
$300 = 105 + 70 + 50 + 25 + 30 + 15 + n$
$\therefore n = 300 - 295 = 5$
Number of people who plays at least two games
$= 30 + 25 + 15 + 5 = 75$
Required percent $= \frac{75}{300} \times 100 = 25\%$

8. **(c)**
9. **(c)** Let the side of smaller square is x cm.
Then side of larger square is $(x + 5)$ cm.
ATQ,
$(x + 5)^2 = 4 \,.\, x^2$
$(x + 5) = \sqrt{4x^2}$
$x + 5 = 2x \quad \Rightarrow \quad x = 5$
$\therefore$ Side of larger square $\; = x + 5 = 5 += 5$
$= 10$ cm.
10. **(b)**



Here, gender of 'S' is not given, so if 'S' is female, then, S will be aunt of R and sister-in-law of Q. And, if 'S' is male then 'S' will be brother of P.
But in both cases 'S' is the aunt of 'T' is necessarily false statement.

TECHNICAL SECTION TEST

1. **(a)** $\lim_{x \to 0} \frac{\sin 4x}{\sin 2x}$
Apply L-hospitals rule $\lim_{x \to 0} \left[\frac{4 \times \cos 4x}{2 \times \cos 2x}\right] = 4/2 = 2$

$\lim_{x \to 0} \frac{\tan x}{x}$

Apply L-hospitals rule $\lim_{x \to 0} \frac{\sec^2 x}{1} = 1$
2. **(c)** For an anisotropic soil permeability is same in all directions $k_x = k_y = k_z$
Laplace's eqn for continuity of 2-D flow is
$$kx \times \frac{d^2 h}{dx^2} + kz \times \frac{d^2 h}{dz^2} = 0$$
$k_x = k_z$
Hence $\frac{d^2 h}{dx^2} + \frac{d^2 h}{dz^2} = 0$
3. **(b)** $m\ddot{z} + kz = 0$
Dividing by m
$$\ddot{z} + \frac{k}{m}(z) = 0, \qquad \text{........(i)}$$

The eqn. for a simple harmonic motion is $\frac{d^2x}{dt^2} + w^2x = 0$

Now comparing (i) with (ii) eq. we get $w^2 = \frac{k}{m}$

$w = \sqrt{k/m}$

4. (a) Expansion of $f(x+h)$ as taylor's series is

$f(x+h) = \frac{f(x)}{0!} + \frac{hf'(x)}{1!} + \frac{h^2 f''(x)}{2!} + \frac{h^3 f'''(x)}{3!} + ...$

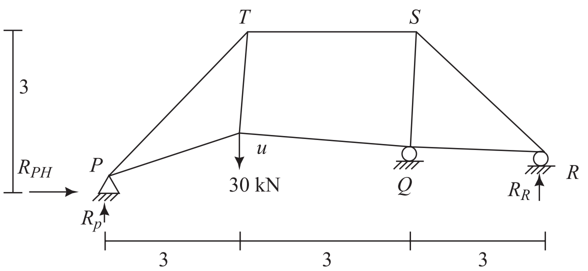
5. (d) In a plane turns, when three members meet at a joint, and the two of them are collinear, and no point load acts at the joint, then third member carries no force. Here *FI*, *FG*, *RS*, *PR* carry zero force.

6. (c) $\varepsilon_a = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta - \frac{1}{2}\nu_{xy}\sin 2\theta$

for normal strain in plane of men strain

$\varepsilon_a = \frac{\varepsilon_x + \varepsilon_y}{2} = \left[\frac{0.0030 + 0.0020}{2}\right] = 0.0025$

7. (a)



$\Sigma F_x = 0$

$R_{PH} = 0$

$\Sigma F_y = 0$

$R_P = 30$

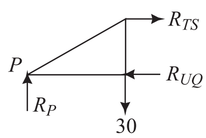
$\Sigma F_x = 0 \quad R_{TS} = R_{UQ}$

$\Sigma_{MP} = 0$

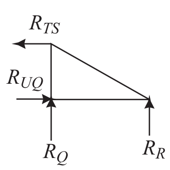
$R_{TS} \times 3 - R_{UQ} \times 1 = -90$

$R_{TS}[3-1] = -90$

$2R_{TS} = -90$



$\boxed{R_{TS} = -45}$



$\Sigma F_y = 0$

$R_Q = -R_R$

$\Sigma M_Q = 0$

$R_{TS} \times 2 + R_R \times 3 = 0$

$-45 \times 2 = -3R_R$

$\boxed{R_R = 30}$
$\boxed{R_Q = -30}$

8. (a) Moment capacity of semi compact inflow shear section = $Z_e f_b d$.

$= SZ_p f_b d \qquad \left(\because \frac{z_e}{z_p} = s\right)$

Moment capacity of semi compact section in high stress

$= \frac{fy}{\gamma mo} z_p \times f_b d$

Hence there is no reduction for semi-compact section

9. (a) Nominal cover = [cover $- \frac{d}{2} - d_{stirrups}$]

$= 50 - \frac{16}{2} - 12 = 30\ mm$

10. (d) Both *Q* and *S*, as one of the angles is less then 30, which must be avoided for a well-conditioned triangle

11. (a) Breaking distance = $\frac{v^2}{254\left[f + \frac{G}{100}\right]}$

here the percentage change in breaking distance

$\Rightarrow \frac{B_1 - B_2}{B_1} \times 100$

Where,

$\Rightarrow B_1 = \frac{v^2}{254\left[f + \frac{G}{100}\right]}$

$B_2 = \frac{v^2}{254\left[f + \frac{2G}{100}\right]}$

$\%\ \text{change} = \frac{\frac{v^2}{254}\left[\frac{1}{f + 0.01G} - \frac{1}{f + 0.02G}\right]}{\frac{v^2}{254} \times \frac{1}{(f + 0.01G)}}$

$= \left[\frac{0.01G}{f + 0.02G}\right] \times 100$

12. (d) Zero, as thermal stress, since base of slab is friction less

13. (a) As we know that

Velocity head = $\frac{v^2}{2g}$

For Critical flow; Velocity head is equal to half of hydraulic depth

So, $\frac{V^2}{2g} = \frac{D}{2}$

$\Rightarrow \frac{\text{Velocity head}}{\text{depth(D)}} = \frac{1}{2}$

14. (d) Irrigation Canal below the bed level of natural stram so the type of cross-drainage structure provided is super passage

15. **(d)** There is no definite relationship between P_A and P_T

16. **(c)** The active thrust act at H/3 from base at the same inclination of that of back fill

17. **(b)** Effective stress = *0*, in quick sand condition

18. **(a)** Ozone is a secondary pollutant

19. **(0.001)**

$$\frac{M}{I} = \frac{f}{y} = \frac{E}{R} \rightarrow \text{ from bending eqn.}$$

$$y = \frac{d}{2} = \frac{500}{2} = 250$$

Curvature

$$\left(\frac{1}{R}\right) = \frac{f}{Ey} = \frac{\text{strain}}{y} = \frac{2.5}{10^4 \times 250} = 1\times 10^{-6} mm^{-1}$$

$= 1 \times 10^{-3}\ m^{-1} = 0.001\ m^{-1}$

20. (100)

Settling velocity is proportional to d^2, hence if 35 mm particles settle 100%, then 45 mm and 50 mm particles settle 100%

21. (0.52)

Max no of vehicles is 5 min = 160 vehicles

Peak hour flow = 1000 vehicles

5 minute peak hour factor

$$= \left[\frac{\text{peak flow}}{12\times(5 \text{ minute traffic })}\right] = \frac{1000}{12\times 160} = 0.52$$

22. (0.081)

$A_1 = \pi/4 \times 0.3^2 = 0.07068$

$A_2 = \pi/4 \times 0.15^2 = 0.01767$

$$\frac{H}{h} = \frac{H}{8\times 10^{-2}} = \left[\frac{\rho_{ng}}{\rho_w} - 1\right] = \left[\frac{13600}{1000} - 1\right] = 12.6$$

So, $H = 8 \times 10^{-2} \times 12.6 = 1.008$ m

$$Q = C_D \times \frac{A_1 A_2 \sqrt{2gH}}{\sqrt{A_1^2 - A_2^2}}, C_D = 1$$

$$= \frac{0.07068\times 0.01767\times\sqrt{2\times 9.81\times 1.008}}{\sqrt{(0.0706)^2 - (0.01767)^2}}$$

$= 0.081\ m^3/s$

23. (17.8)

Risk of flood = $1 - q^n$ where $n = 5$

$0.25 = 1 - q^5$ [$\because$ Risk = 0.25]

$q^5 = 0.75$

$q = 0.944$

$P + q = 1$

hence, $P = 1 - q$

and $T = 1/P$

$$or\ \left(p = \frac{1}{T}\right)$$

$$So,\ \frac{1}{T} = 1 - 0.944$$

$T = 17.85714 \approx 17.8$ years

24. (2094.9)

As we know that dry density $\gamma_{dry} = \dfrac{G_s \gamma_w}{1+e}$

$Se = wG$

$$e = \frac{w_G}{s} = \frac{0.1\times 2.65}{1} = 0.265$$

$$\gamma_{dry} = \frac{2.65\times 1000}{1.265}$$

$= 2094.8\ kg/m^3$

25. (4) As we know that vertical stress $\sigma_z = \dfrac{3}{2\pi}\times\dfrac{Q}{Z^2}$

$$\sigma_{z_1} = \frac{3}{2\pi}\times\frac{500}{2^2}$$

$$\sigma_{z_2} = \frac{3}{2\pi}\times\frac{500}{4^2}$$

$$\frac{\sigma_{z_1}}{\sigma_{z_2}} = 4$$

26. **(b)** $\sqrt[x]{x} = y$

$y = x^{1/x}$

$$\log y = \frac{\log x}{x}$$

$Y = e^{\log x/x}$

$$\text{i.e. } f(x) = \frac{\log x}{x}$$

To find max or min

$$f'(x) = \left[\frac{\frac{x}{x} - \log x}{x^2}\right] = \left[\frac{1-\log x}{x^2}\right] = 0$$

$1 = \log x$

$x = e$

Thus x is maximum or minimum at e to find which take $f''(x)$

$$f''(x) = \left[\frac{x^2\times\left(\frac{-1}{x}\right) - 2x(-\log x + 1)}{x^4}\right]$$

$$= \left[\frac{-x\times 3 + 2x\times\log x}{x^4}\right]$$

At $x = e$

$$f''(x) = \frac{-e}{e^4} < 0, \text{ hence } f(x) \text{ is maximum at } x = e$$

27. **(a)** $$\frac{\delta v}{\delta t} = \beta\times\frac{\delta^2 v}{\delta x^2} \quad \ldots(1)$$

Approximating this is forward difference

$$\frac{\delta v}{\delta t} = \frac{v_i^{n+1} - v_i^n}{\Delta t} \quad \ldots(2)$$

Using central difference approximation to $\dfrac{d^2 v}{dx^2}$

$$\frac{d^2v}{dx^2_{at\to x_1}} = \frac{v^n{}_{i+1} - 2v_i^n + v^n{}_{i-1}}{\Delta x^2} \quad \ldots(3)$$

Now substitute (2) *and* (3) in (i)

$$\frac{v_i^{(n+1)} - v_i^n}{\Delta t} = \beta\left[\frac{v^{(n)}{}_{i+1} - 2v_1^{(n)} + v_i^{(n)}{}_{-1}}{(\Delta x)^2}\right]$$

28. (0.017)

By the mannings equation velocity

$$(V) = \frac{1}{n}\ R^{2/3}\ S^{1/2}$$

$$\left[\begin{array}{l}\because R = A/P\dfrac{5\times 2}{5+4} - 1.11 \\ S = 0.001, V = 2m/\text{sec.}\end{array}\right]$$

$$\text{So, } 2 = \frac{1}{n} \times (1.11)^{2/3} \times (0.001)^{1/2}$$

$n = 0.017$

29. **(a)** All are true

30. **(d)** As given that,

$x = \psi \ln \phi$

$$\psi = \frac{x}{\ln \psi}$$

And, $y = \phi \ln \psi$

$$\phi = \frac{y}{\ln \psi}$$

$$\text{So, } \psi = \frac{x}{\ln y - \ln(\ln \psi)}$$

$$\frac{d\psi}{dx} = \frac{\ln y - \ln(\ln \psi) - x\left(\dfrac{-1}{\ln \psi}.\dfrac{1}{\psi}\dfrac{d\psi}{dx}\right)}{[\ln y - \ln(\ln \psi)]^2}$$

$$\ln y - \ln(\ln \psi) = \frac{x}{\psi}$$

$$\frac{d\psi}{dx} = \frac{1 + \dfrac{1}{\ln \psi}\dfrac{d\psi}{dx}}{x/\psi}$$

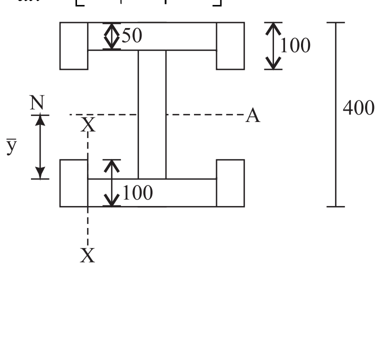
$$\frac{d\psi}{dx}\left(\frac{x}{\psi} - \frac{1}{\ln \psi}\right) = 1$$

$$\frac{d\psi}{dx} = \frac{\psi \ln \psi}{x \ln \psi - \psi}$$

Replacing x by ψ is ϕ.

$$\frac{d\psi}{dx} = \left[\frac{\ln \psi}{\ln \phi \ln \psi - 1}\right]$$

31. **(a)**



$$\bar{y} = 200 - \frac{100}{2} = 150 \text{ mm}, I = 1.5 \times 10^9 \text{ mm}^4$$

Area(A) = $50 \times 100 = 50 \times 10^2$ mm^2, F= 8000N

$$SF_x = \frac{FA\bar{Y}}{I}$$

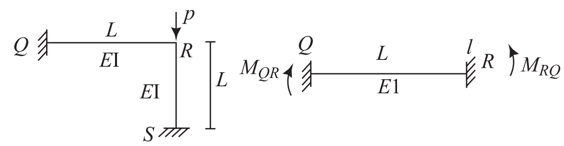
$$= \left[\frac{8000 \times 50 \times 1000 \times 150}{1.5 \times 10^9}\right] = 40 \text{ N/mm}$$

this shear flow acts longitudinally throughout section X–X, this shear force is resisted by nails.

Hence shear resisted = spring of nails $\times SF_x$

$= 60 \times 40 = 240\ N$

32. **(c)**

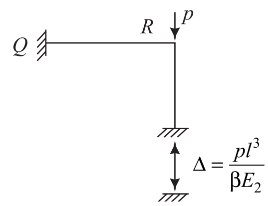


$$M_{QR} = \frac{2EI}{L}\left[Q_R - \frac{3\Delta}{l}\right] + M_{FQR}$$

$$M_{RQ} = \frac{2EI}{L}\left[2Q_R - \frac{3\Delta}{l}\right] + M_{FRQ}$$

Here $\Delta = 0, M_{FRQ} = M_{FQR} = 0$

$$\text{Hence } M_{QR} = \frac{2EI}{L}Q_R$$

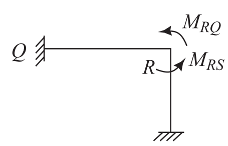


$$M_{RQ} = \frac{4EI}{l}Q_R$$

$\Sigma MQ = 0$

$M_{QR} + M_{RQ} + p \times l = 0$

$$\frac{-12EI}{l^2} \times \Delta + \frac{6EI\theta_R}{l} + Pl = 0$$



$M_{RQ} + M_{RS} = 0$

$$\frac{8EI\theta_R}{L} - \frac{6EI\Delta}{L^2} = 0$$

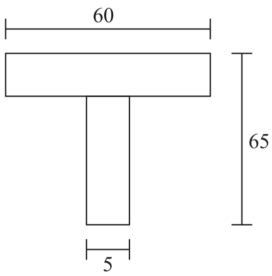
$$\frac{8EI\theta_R}{L} - \frac{6EI}{L^2}\left[\frac{PL^3}{\beta EI}\right] = 0$$

$$\frac{-60PL}{8\beta} + PL = 0$$

$8\beta = 60$

$\beta = 7.5$

33. (c)



For fully elastic case

$$\bar{y}_1 = \frac{60\times5\times2.5+60\times5\times(5+30)}{60\times5+60\times5}$$

= 18.75

For fully plastic case

$\bar{y}_2 = 5$

$\Delta\bar{y} = \bar{y}_1 - \bar{y}_2$ = 18.75 – 5 = 13.75 mm

34. (b) As we know that settling velocity $(V_s) = \frac{gd^2(\rho s - \rho w)}{18\mu}$

$$= \left[\frac{9.8\times(25\times10^{-6})^2\times(2.5-1)\times1000}{18\times1\times10^{-3}}\right]$$

= 5.104×10^{-4} m/sec

Particle removal efficiency

$$\eta = \frac{v_s}{v_o}\times100\%$$

Where, $V_0 = Q/A = [Q/L \times B] = \frac{0.2}{8\times32}$

= 7.812×10^{-4} m/sec

So, $\eta = \frac{5.104}{7.812}\times100\% = 65.33\%$

35. (a) True length = [L – 0.05]

= [30 – 0.05] = 29.95 m

Corrected length $= \frac{\text{True length}}{L} \times$ distance

$$L_C = \frac{29.95}{30}\times285.5$$

= 285.0241 m

In slope horizontal length = $L_C \times \cos\theta$

$$\cos\theta = \frac{10}{\sqrt{10^2+1^2}} = 0.995$$

= 285.0241 × 0.995 = 283.6 m

36. (105)

As per IS 800:2007

Equivalent maximum resultant stress due to combination of normal & shear stress

$$F_e = \sqrt{f_a^2 + 3q^2}$$

$$q = \frac{350\times10^3}{2ht}, \; t = K\times S$$

= 0.7 × 10 = 7 mm

$$q = \frac{350\times10^3}{2\times500\times7} = 50 \text{ N/mm}^2.$$

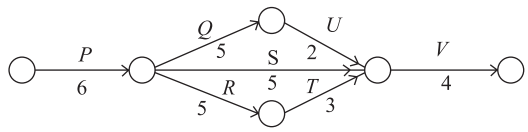
$$f_a = \frac{M}{I}\times y_{max}$$

$$f_a = \frac{p\times e}{2\times7\times\frac{500^3}{12}}\times y_{max}$$

$$= \frac{350\times10^3\times100}{14\times\frac{500^3}{12}} = 60 \text{ N/mm}^2.$$

$$F = \sqrt{60^2+3\times50^2} = 105.3 \text{ N/mm}^2$$

37. (149500)



Activity	t_n	t_c	C_n	C_c	Cost slope/day
P	6	4	15000	25000	5000/d
Q	5	2	6000	12000	2000
R	5	3	8000	9500	750
S	6	3	7000	10000	1000
T	3	2	6000	9000	3000
U	2	1	4000	6000	2000
V	4	2	20000	28000	4000

For normal duration

Total cost = 66000 + 5000 × 18 = 156000

crashing *R by* 1 day

then total cost = 6600 + 750 + 5000 × 17 = 151750

crashing *Q* & *R* by 1 day=

(66750 + 2000 + 750 + 5000 × 16) = 149500

38. (50.94)

Volume of aggregate $= \frac{187.5}{2.5\times1000} = 0.075 \text{ m}^3$

Volume of box = 0.125 m^3

Volume of words = V – V_C = 0.125 – 0.075 = 0.05 m^3

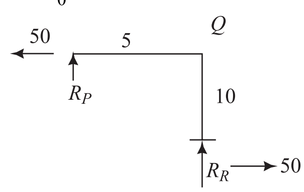
Volume of water absorbed $= \frac{0.5}{100}\times\frac{187.5}{1000}$

$= 9.375 \times 10^{-4}$ m^3

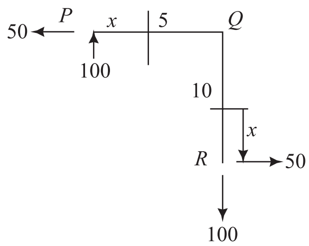
Total volume of water = 9.375×10^{-4} + 0.05 = 0.0509 m^3

Mass of water = Volume × ρ = 0.0509 × 1000 = 50.94 kg

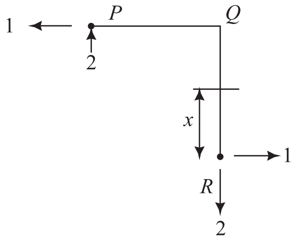
39. (25) $\delta = \int_0^L \frac{Mm\,dx}{EI}$



$\Sigma M_P = 0, R_P - R_R = 0$
$50 \times 10 = R_R \times 5$
$R_R = 100\ (\downarrow)$
$R_P = 100\ (\uparrow)$
for M



For, Mn
at $PQ = 100x$
at $RQ = 50x$
for m



For, Mn
at $PQ = 2x$
at $RQ = x$

$$\int H_R = \left[\int_0^L \frac{Mx\,mx}{EI}dx\right]_{PQ} + \left[\int_0^L \frac{Mx\,mx}{EI}dx\right]_{RQ}$$

$$= \int_0^5 \frac{200x^2}{10^6}dx + \int_0^{10} \frac{50x^2}{10^6}dx = \frac{1}{10^6}[200\times 25 + 50\times 100]$$

$= 25 \times 10^{-3}\ m = 25\ mm$

40. (41.07)

1 mole NO_2 occupies 22.4 L of volume
$1\ L = 10^{-3}\ m^3$
$22.4\ L = 22.4 \times 10^{-3}\ m^3$
$1\ m^3$ contains $\dfrac{1}{22.4\times 10^{-3}} = 44.64$ mol
1 mol of NO_2 weight = 32 + 14 = 46 *gm*
$1\ m^3\ NO_2$ weight = 44.64 × 46 = 2053.57 gm
Hence, 0.02 ppm of NO_2 contain 41.07 g/$10^6\ m^3$

41. (1.211)

As we know that
Back wash velocity (V_B)

$V_B = \dfrac{Q_B}{L\times B} = \dfrac{0.06}{4\times 3} = 5 \times 10^{-3}$ m/s

Bed porosity (n) = 0.4

porosity of expanded bed (n_e) = $\left(\dfrac{V_B}{V_S}\right)^{0.22}$

$n_e = \left[\dfrac{5\times 10^{-3}}{0.05}\right]^{0.22}$ [∵ $V_s = 0.05$]

= 0.6025
As we also know that,

Expanded bed depth (De) = $D\left[\dfrac{1-n}{1-n_e}\right]$

$= 0.8\left[\dfrac{1-0.4}{1-0.6025}\right]$ [∵ D = 0.8 given]

= 1.211 m/s

42. (8) As we know that the Modal of Micro-organism

$N_t = N_o\, e^{-kt}$

$\dfrac{N_t}{N_o} = e^{-kt}$

$\dfrac{N_t - N_o}{N_o} = (1 - e^{-kt}) \times 100$

$\dfrac{99}{100} = 1 - e^{-kt}$

$0.99 = 1 - e^{-0.23\,t}$
t = 20.22 minute

$V = Q \times t = \dfrac{36}{60} \times 20.22 = 12.013$

$L = \dfrac{V}{B\times H} = \dfrac{12.013}{1\times 1.5}$

= 0.008 ≈ 8 m

43. (100)

$HOI = RL + BS$ Where BS = (1 + 0.4) = 1.4 m, RL = 100
= 100 + 1.4 = 101.4 m
RL of theodolite station = (101.4 – theodolite hight)
= (101.4 – 1.4) = 100 m

44. (6) As given that D.E.

$x^2\dfrac{d^2y}{dx^2} - 2x\dfrac{dy}{dx} + 2y = 0$ ....(i)

$\Rightarrow [x^2D^2 - 2xD + 2]y = 0$

Let XD = θ, $x^2D^2 = \theta(\theta - 1)$ Where,

$x = e^z$ or z = log x

& $\theta = \dfrac{d}{dZ}$

$[\theta(\theta - 1) - 2\theta + 2]y = 0$

So the A.E is $(\theta^2 - 3\theta + 2] = 0$

$\Rightarrow (\theta - 2)(\theta - 1) = 0$

θ = 1, 2 real & distinct

The solution of eqn. (i) *(DE)* = $y = C_1 e^z + C_2 e^{2z}$

$y = C_1 x + C_2 x^2$ [∵ $x = e^z$]
$y(1) = C_1 + C_2 = 0$
$y(2) = 2C_1 + 4C_2 = 2$
by solving it $C_1 = -1, C_2 = 1$
So, $y = -x + x^2$
$y(3) = -3 + 9 = 6$

45. (1800)

Maximum flow

$$Q_{\max} = \frac{V_S \times K_S}{4} = \left[\frac{60 \times 120}{4}\right] = 1800 \text{ vehicles/hr}$$

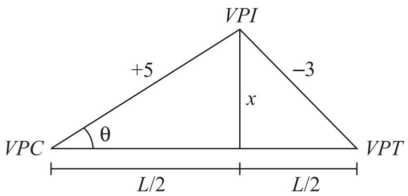
46. (0.18)

As given that, $\lambda = 360$ veh/hr $= 0.1$ veh/sec

Probability of head way space b/w 6 to 10 seconds by Poissons distribution

$= e^{-\lambda t_1} - e^{-\lambda t_2} = e^{-0.1 \times 6} - e^{-0.1 \times 10} = 0.18$

47. (10)



$$\tan\theta = \frac{5}{100} = \frac{x}{200}$$

$x = 10$ m

48. (700)

As we know that,

$$\text{Length of tie bar} = \left[t + \frac{d\sigma_{st}}{2 \times \sigma_b}\right]$$

$t = 10$ mm, $\sigma_b = 2$ MPa

$d = 12$ mm, $\sigma_{st} = 230$ MPa

$$\text{Length} = \left[10 + \frac{12 \times 230}{2 \times 2}\right] = 700 \text{ mm}$$

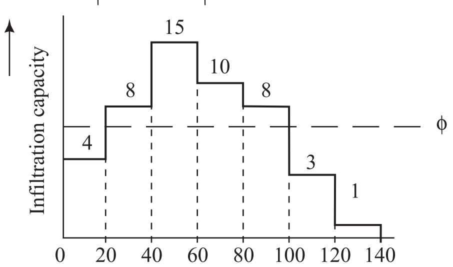
49. (7.25)

Depth of infiltration = Area of hyetograph above curve

$$= \left[\frac{20}{60} \times 15 + 10 \times \frac{20}{60} + \frac{20}{60} \times 8\right] \frac{-10+4}{2}$$

$$= \left[5 + \frac{10}{3} + \frac{8}{3}\right] - 7 = 4 \text{ mm}$$

Assume $\phi \le 8$ and $\phi \ge 4$.

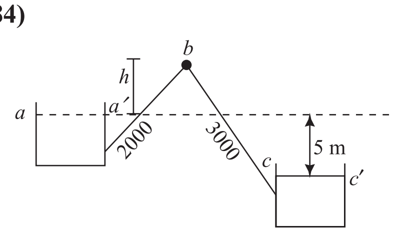


Depth of infiltration

$$\Rightarrow \left[\frac{20}{60} \times (8-\phi) + \frac{20}{60}(15-\phi) + \frac{20}{60}(10-\phi) + \frac{20}{60}(8-\phi)\right] = 4$$

$\phi = 7.25$ mm/hr

50. (5.84)



Applying bernoulli's theorem at aa' and cc'

$$\left[\frac{pa}{\rho g} + \frac{v_a^2}{2g} + za\right] - \left[\frac{pc}{\rho g} + \frac{v_c^2}{2g} + z_c\right] = -h_f$$

$$10.3 + z_a - 10.3 - z_c = \frac{-flv^2}{2gd}$$

$$z_a - z_c = \frac{-f\,lv^2}{2gd}$$

$$5 = \frac{f\,lv^2}{2gd}$$

$$V = \frac{Q}{\pi/4d^2}$$

$$\text{hence } 5 = \frac{f\,lQ^2}{12d^5}$$

$$5 = \frac{0.02 \times 5000 \times Q^2}{12 \times (0.1)^5}$$

$$Q = \sqrt{\frac{5 \times 12 \times (0.1)^5}{0.02 \times 5000}}$$

$Q = 2.46 \times 10^{-3}$ m^3/sec

Applying bernoulli theorem at aa' and b

$$\left[\frac{pa}{\rho g} + \frac{va^2}{2g} + z_a\right] - \left[\frac{pb}{\rho g} + \frac{vb^2}{2g} + z_b\right] = -h_f$$

$$= 10.3 + za - \frac{pb}{\rho g} - \frac{Q^2}{\pi/4d^2 \times 2g} - z_b = -h_f = 10.3 - (h)$$

$$= 2.5 + \frac{(2.46 \times 10^{-3})^2}{2 \times 9.81 \times \pi/4 \times 0.1^2} + \frac{0.02 \times 2000 \times (2.46 \times 10^3)}{12 \times (0.1)^5}$$

$\Rightarrow 10.3 - h = 4.46$

$h = 5.84$ m

51. (8) Velocity distribution for flow b/w two infinite parallel plates

$$u = \frac{Vy}{h} - \frac{1}{2\mu}\frac{dp}{dx}\left[hy - y^2\right]$$

v - is the velocity of top plate

h - gap b/w plates

$$\frac{du}{dy} = \frac{v}{h} - \frac{1}{2\mu}\frac{dp}{dx}\left[h - 2y\right]$$

$$\text{at } \quad y = 0, \ \frac{v}{h} - \frac{1}{2\mu}\frac{dp}{dx}h$$

$$\tau_y = 0 = \mu\left[\frac{v}{h} - \frac{1}{2\mu}\frac{dp}{dx}h\right]$$

$$\tau_y = 0 = \left[\frac{v\mu}{h} - \frac{1}{2}\frac{dp}{dx}h\right]$$

equating this to zero.

$$\frac{v\mu}{h} = \frac{1}{2}\frac{dp}{dx}h$$

$$\frac{dp}{dx} = \frac{2v\mu}{h^2}$$

$$= \frac{2\times1\times10^{-2}\times1\times10^{-2}}{(5\times10^{-3})^2} = 8 \text{ Mpa/m}$$

52. (1224.07)

For clays $Q_\mu = Q_{pf}$

$= A_s \times f_s = (\pi Ld)\times(\alpha C)$

$$= \left[\frac{22}{7}\times0.6\times12\times0.5\times110\right] = 1224.07 \text{ KN}$$

53. (11.09)

When seepage is parallel to slope

$$\text{F.O.S.} = \left[\frac{\gamma' z.\cos^2\beta\tan\phi}{\gamma_{sat}.z.\cos\beta.\sin\beta}\right]$$

$$\text{FOS} = \frac{\gamma'\tan\phi}{\gamma_{sat}\tan\beta}$$

$$1.5 = \frac{(20-9.81)\tan30}{9.81\times\tan\beta}$$

$\tan\beta = 0.599$

$\beta = \tan^{-1}(0.599) = 11.09°$

54. (2.02)

$$\text{FOS against shear failure (F)} = \left[\frac{\text{strength}}{\text{Applied load}}\right]$$

$$F = (C + \sigma\tan\phi)\times\frac{A}{P}$$

Where

$$\sigma = \frac{N}{A} = \frac{24\times37.5\times7.5}{37.5} = 180 \text{ KN/m}^2$$

$$F = \left[\frac{17+180\times\tan25\times37.5}{1875}\right] = 2.02$$

55. (270)

$q_u = 1.3\ CN_C + \gamma D_f N_q + 0.4\gamma.B.N\gamma$

$= 1.3\ CN_C + \gamma D_f Nq + 0.4\ \gamma B\ N\gamma$

$C = 0$, for sand

$q_u = \gamma D_f Nq + 0.4\ \gamma B\ N\gamma$

$600 = 15\times Nq + 0.4\times15\times4\times18.75$

$15\ Nq = 600 - (450)$

$Nq = 10$

When $D_f = 2m$

$qu = 15\times2\times10 + 0.4\times15\times4\times18.75$

$= 750 \text{ KN/m}^2$

$q_{nu} = q_u - \gamma D_f$

$= 750 - 15\times2$

$= 720 \text{ KN/m}^2$

$$q_s = \frac{q_{nu}}{F} + \nu D_f$$

$$= \frac{720}{3} + 30$$

$= 270\ KPa$

GATE CIVIL ENGINEERING SOLVED PAPER

2019 Set-2

Duration: 3 hrs **Maximum Marks: 100**

INSTRUCTIONS

1. There are a total of 65 questions carrying 100 marks.
2. The subject specific GATE paper section consists of 55 questions. The GA section consists of 10 questions.
3. Questions are of Multiple Choice Question (MCQ) or Numerical Answer type. A multiple choice question will have four choices for the answer with only one correct choice. For numerical answer type questions, the answer is a number and no choices will be given.
4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions will result in NEGATIVE marks. For all 1 mark questions, $\frac{1}{3}$ mark will be deducted for each wrong answer. For all 2 marks questions, $\frac{2}{3}$ mark will be deducted for each wrong answer.
5. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE.**

GENERAL APTITUDE TEST

QUESTIONS 1 TO 5 CARRY ONE MARK EACH

1. Daytime temperatures in Delhi can _______ 40°C.

(a) get (b) stand
(c) reach (d) peak

2. The growth rate of ABC Motors in 2017 was the same _______ XYZ Motors in 2016.

(a) as off (b) as those of
(c) as that off (d) as that of

3. Suresh wanted to lay a new carpet in his new mansion with an area of 70 × 55 sq. mts. However an area of 550 sq. mts. had to be left out for flower pots. If the cost of carpet is Rs. 50 per sq. mts., how much money (in Rs.) will be spent by Suresh for the carpet now?

(a) Rs. 1,65,000 (b) Rs. 1,92,500
(c) Rs. 2,75,000 (d) Rs. 1,27,500

4. A retaining wall with measurements 30m × 12m × 6m was constructed with bricks of dimensions 8cm × 6cm × 6cm. If 60% of the wall consists of bricks, the number of bricks used for the construction is __________ lakhs.

(a) 30 (b) 40
(c) 45 (d) 75

5. Hima Das was __________ only Indian athlete to win __________ gold for India.

(a) the, many (b) the, a
(c) an, a (d) an, the

QUESTIONS 6 TO 10 CARRY TWO MARKS EACH

6. Mohan, the manager, wants his four workers to work in pairs. No pair should work for more than 5 hours. Ram and John have worked together for 5 hours. Krishna and Amir have worked as a team for 2 hours. Krishna does not want to work with Ram. Whom should Mohan allot to work with John, if he wants all the workers to continue working?

(a) Amir (b) Krishna
(c) Ram (d) None of the three

7. Population of state X increased by x% and the population of state Y increased by y% from 2001 to 2011. Assume that x is greater than y. Let P be the ratio of the population of state X to state Y in a given year. The percentage increase in P from 2001 to 2011 is __________.

(a) $\frac{x}{y}$ (b) $x - y$
(c) $\frac{100(x-y)}{100+x}$ (d) $\frac{100(x-y)}{100+y}$

8. *The Newspaper* reports that over 500 hectares of tribal land spread across 28 tribal settlements in Mohinitampuram forest division have already been "alienated". A top forest official said, "First the tribals are duped out of their land holdings. Second, the families thus rendered landless are often forced to encroach further into the forests".

On the basis of the information available in the paragraph, __________ is/are responsible for duping the tribals.

(a) forest officials
(b) landless families
(c) *The Newspaper*
(d) it cannot be inferred who

9. An oil tank can be filled by pipe X in 5 hours and pipe Y in 4 hours, each pump working on its own. When the oil tank is full and the drainage hole is open, the oil is drained in 20 hours. If initially the tank was empty and someone started the two pumps together but left the drainage hole open, how many hours will it take for the tank to be filled? (Assume that the rate of drainage is independent of the Head)

(a) 1.50 (b) 2.00
(c) 2.50 (d) 4.00

10. "Popular Hindi fiction, despite – or perhaps because of – its wide reach, often does not appear in our cinema. As ideals that viewers are meant to look up to rather than identify with, Hindi film protagonists usually read books of aspirational value: textbooks, English books, or high value literature."

Which one of the following CANNOT be inferred from the paragraph above?

(a) Though popular Hindi fiction has wide reach, it often does not appear in the movies
(b) Protagonists in Hindi movies, being ideals for viewers, read only books of aspirational value
(c) Textbooks, English books or high literature have aspirational value, but not popular Hindi fiction
(d) People do not look up to writers of textbooks, English books or high value literature

TECHNICAL SECTION TEST

QUESTIONS 1 TO 25 CARRY ONE MARK EACH

l. Euclidean norm (length) of the vector $[4 \ \ -2 \ \ -6]^T$ is

(a) $\sqrt{12}$ (b) $\sqrt{24}$
(c) $\sqrt{48}$ (d) $\sqrt{56}$

2. The Laplace transform of $\sinh(at)$ is

(a) $\dfrac{a}{s^2-a^2}$ (b) $\dfrac{a}{s^2+a^2}$
(c) $\dfrac{s}{s^2-a^2}$ (d) $\dfrac{s}{s^2+a^2}$

3. The following inequality is true for all x close to 0.

$$2-\frac{x^2}{3}<\frac{x\sin x}{1-\cos x}<2$$

What is the value of $\lim\limits_{x\to 0}\dfrac{x\sin x}{1-\cos x}$?

(a) 0 (b) 1/2
(c) 1 (d) 2

4. What is curl of the vector field $2x^2y\mathbf{i}+5z^2\mathbf{j}-4yz\mathbf{k}$?

(a) $6z\mathbf{i}+4x\mathbf{j} - 2x^2\mathbf{k}$
(b) $6z\mathbf{i}-8xy\mathbf{j}+2x^2y\mathbf{k}$
(c) $-14z\mathbf{i}+6y\mathbf{j}+2x^2\mathbf{k}$
(d) $-14z\mathbf{i}-2x^2\mathbf{k}$

5. A closed thin-walled tube has thickness, t, mean enclosed area within the boundary of the centerline of tube's thickness, A_m, and shear stress, τ. Torsional moment of resistance, T, of the section would be

(a) $0.5\tau A_m t$ (b) $\tau A_m t$
(c) $2\tau A_m t$ (d) $4\tau A_m t$

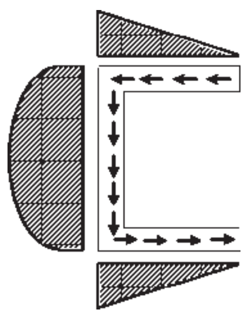
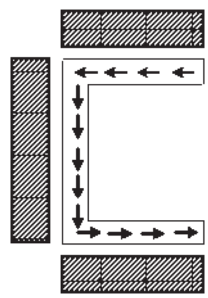
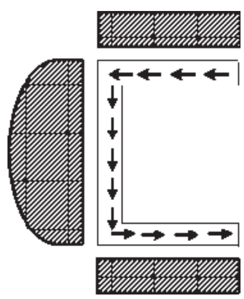
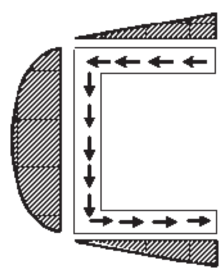
6. A steel column is restrained against both translation and rotation at one end and is restrained only against rotation but free to translate at the other end. Theoretical and design (IS: 800-2007) values, respectively, of effective length factor of the column are

(a) 1.0 and 1.0 (b) 1.2 and 1.0
(c) 1.2 and 1.2 (d) 1.0 and 1.2

7. If the fineness modulus of a sample of fine aggregates is 4.3, the mean size of the particles in the sample is between

(a) 150 μm and 300 μm (b) 300 μm and 600 μm
(c) 1.18 mm and 2.36 mm (d) 2.36 mm and 4.75 mm

8. For a channel section subjected to a downward vertical shear force at its centroid, which one of the following represents the correct distribution of shear stress in flange and web?

(a)

(b)

(c)

(d)


9. Which one of the following options contains ONLY primary air pollutants?

(a) Hydrocarbons and nitrogen oxides
(b) Hydrocarbons and ozone
(c) Ozone and peroxyacetyl nitrate
(d) Nitrogen oxides and peroxyacetyl nitrate

10. Analysis of a water sample revealed that the sample contains the following species.

CO_3^{2-}, Na^+, H^+, PO_4^{3-}, Al^{3+}, H_2CO_3, Cl^-, Ca^{2+}, Mg^{2+}, HCO_3^-, Fe^{2+}, OH^-

Concentrations of which of the species will be required to compute alkalinity?

(a) CO_3^{2-}, H^+, HCO_3^-, OH^-

(b) CO_3^{2-}, H^+, H_2CO_3, HCO_3^-

(c) CO_3^{2-}, H_2CO_3, HCO_3^-, OH^-

(d) H^+, H_2CO_3, HCO_3^-, OH^-

11. Stractural failures considered in the mechanistic method of bituminous pavement design are

(a) Fatigue and Rutting (b) Fatigue and Shear

(c) Rutting and Shear (d) Shear and Slippage

12. A solid sphere of radius, r, and made of material with density, ρ_s, is moving through the atmosphere (constant pressure, p) with a velocity, v. The net force ONLY due to atmospheric pressure (F_p) acting on the sphere at any time, t, is

(a) $\pi r^2 p$ (b) $4\pi r^2 p$

(c) $\frac{4}{3}\pi r^3 \rho_s \frac{dv}{dt}$ (d) zero

13. The velocity field in a flow system is given by $v = 2\mathbf{i} + (x+y)\mathbf{j} + (xyz)\mathbf{k}$. The acceleration of the fluid at (1, 1, 2) is

(a) $2\mathbf{i} + 10\mathbf{k}$ (b) $4\mathbf{i} + 12\mathbf{k}$

(c) $\mathbf{j} + \mathbf{k}$ (d) $4\mathbf{j} + 10\mathbf{k}$

14. An inflow hydrograph is routed through a reservoir to produce an outflow hydrograph. The peak flow of the inflow hydrograph is P_I and the time of occurrence of the peak is t_I. The peak flow of the outflow hydrograpli is P_O and the time of occurrence of the peak is t_O. Which one of the following statements is correct?

(a) $P_I < P_O$ and $t_I < t_O$

(b) $P_I < P_O$ and $t_I > t_O$

(c) $P_I > P_O$ and $t_I < t_O$

(d) $P_I > P_O$ and $t_I > t_O$

15. An earthen dam of height H is made of cohesive soil whose cohesion and unit weight are c and γ, respectively. If the factor of safety against cohesion is F_C, the Taylor's stability number (S_n) is

(a) $\frac{\gamma H}{cF_c}$ (b) $\frac{cF_c}{\gamma H}$

(c) $\frac{c}{F_c \gamma H}$ (d) $\frac{F_c \gamma H}{c}$

16. The notation "SC" as per *Indian Standard Soil Classification System* refers to

(a) Sandy clay (b) Silty clay

(c) Clayey silt (d) Clayey sand

17. An anisotropic soil deposit has coefficient of permeability in vertical and horizontal directions as k_z and k_x, respectively. For constructing a flow net, the horizontal dimension of the problem's geometry is transformed by a multiplying factor of

(a) $\sqrt{\frac{k_z}{k_x}}$ (b) $\sqrt{\frac{k_x}{k_z}}$ (c) $\frac{k_x}{k_z}$ (d) $\frac{k_z}{k_x}$

18. The value of the function $f(x)$ is given at n distinct values of x and its value is to be interpolated at the point x^*, using all the n points. The estimate is obtained first by the Lagrange polynomial, denoted by I_L, and then by the Newton polynomial, denoted by I_N. Which one of the following statements is correct?

(a) I_L is always greater than I_N

(b) I_L and I_N are always equal

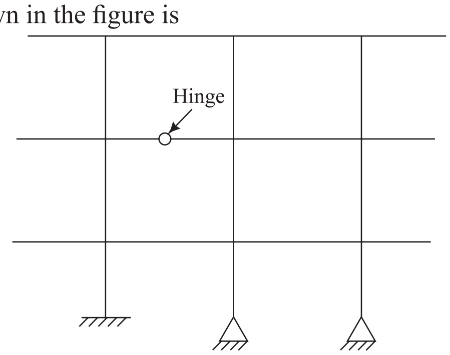
(c) I_L is always less than I_N

(d) No definite relation exists between I_L and I_N

19. The speed-density relationship in a mid-block section of a highway follows the Greenshield's model. If the free flow speed is v_f and the jam density is k_j, the maximum flow observed on this section is

(a) $v_f k_j$ (b) $\frac{v_f k_j}{2}$ (c) $\frac{v_f k_j}{4}$ (d) $\frac{v_f k_j}{8}$

20. The degree of static indeterminacy of the plane frame as shown in the figure is



21. The characteristic compressive strength of concrete required in a project is 25 *MPa* and the standard deviation in the observed compressive strength expected at site is 4 *MPa.* The average compressive strength of cubes tested at different water-cement (w/c) ratios using the same material as is used for the project is given in the table.

w/c (%)	45	50	55	60
Average compressive strength of cubes (*MPa*)	35	25	20	15

The water-cement ratio (in *percent, round off to the* ***lower integer***) to be used in the mix is __________

22. The data from a closed traverse survey PQRS (run in the clockwise direction) are given in the table

Line	Included angle (in *degrees*)
PQ	88
QR	92
RS	94
SP	89

The closing error for the traverse PQRS (in *degrees*) is __________

23. A vehicle is moving on a road of grade +4% at a speed of 20 m/s. Consider the coefficient of rolling friction as 0.46 and acceleration due to gravity as 10 m/s^2. On applying brakes to reach a speed of 10 *m/s,* the required braking distance (in *m, round off to nearest integer*) along the horizontal, is __________

24. The command area of a canal grows only one crop, i.e., wheat. The base period of wheat is 120 days and its total water requirement, Δ, is 40 cm. If the canal discharge is 2 m^3/s, the area, in *hectares*, rounded off to the nearest integer, which could be irrigated (*neglecting all losses*) is __________

25. Construction of a new building founded on a clayey soil was completed in January 2010. In January 2014, the average consolidation settlement of the foundation in clay was recorded as 10 *mm.* The ultimate consolidation settlement was estimated in design as 40 *mm.* Considering double drainage to occur at the clayey soil site, the expected consolidation settlement in January 2019 (in *mm, round off to the nearest integer*) will be __________

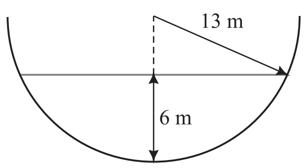
QUESTIONS 26 TO 55 CARRY TWO MARKS EACH

26. The probability density function of a continuous random variable distributed uniformly between *x* and *y* (for $y > x$) is

(a) $\dfrac{1}{x-y}$ (b) $\dfrac{1}{y-x}$

(c) $x-y$ (d) $y-x$

27. Consider the hemi-spherical tank of radius 13 *m* as shown in the figure (*not drawn to scale*). What is the volume of water (in m^3) when the depth of water at the centre of the tank is 6 *m*?



(a) 78π (b) 156π (c) 396π (d) 468π

28. An ordinary differential equation is given below.

$$\left(\frac{dy}{dx}\right)(x\ln x) = y$$

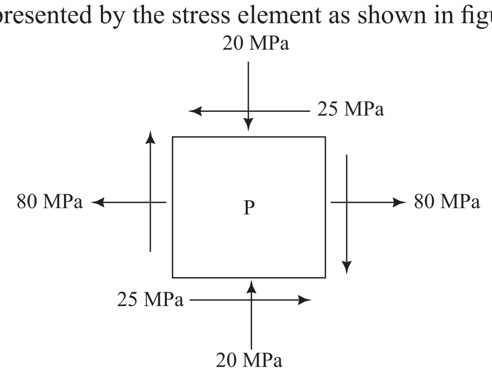
The solution for the above equation is

(*Note: K denotes a constant in the options*)

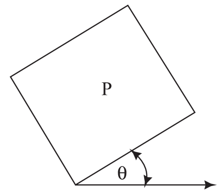
(a) $y = Kx\ln x$ (b) $y = Kxe^{x}$

(c) $y = Kxe^{-x}$ (d) $y = K\ln x$

29. For a plane stress problem, the state of stress at a point *P* is represented by the stress element as shown in figure.



By how much angle (θ) in *degrees* the stress element should be rotated in order to get the planes of maximum shear stress?



(a) 13.3 (b) 26.6 (c) 31.7 (d) 48.3

30. The critical bending compressive stress in the extreme fibre of a structural steel section is 1000 *MPa.* It is given that the yield strength of the steel is 250 *MPa*, width of flange is 250 *mm* and thickness of flange is 15 *mm.* As per the provisions of IS:800-2007, the non-dimensional slenderness ratio of the steel cross-section is

(a) 0.25 (b) 0.50 (c) 0.75 (d) 2.00

31. In the context of provisions relating to durability of concrete, consider the following assertions:

Assertion (1): As per IS 456-2000, air entrainment to the extent of 3% to 6% is required for concrete exposed to marine environment.

Assertion (2): The equivalent alkali content (in terms of Na_2O equivalent) for a cement containing 1% and 0.6% of Na_2O and K_2O, respectively, is approximately 1.4% (rounded to 1 decimal place).

Which one of the following statements is CORRECT?

(a) Assertion (1) is FALSE and Assertion (2) is TRUE

(b) Assertion (1) is TRUE and Assertion (2) is FALSE

(c) Both Assertion (1) and Assertion (2) are FALSE

(d) Both Assertion (1) and Assertion (2) are TRUE

32. Chlorine is used as the disinfectant in a municipal water treatment plant. It achieves 50 *percent* of disinfection efficiency measured in terms of killing the indicator microorganisms (*E-Coli*) in 3 *minutes.* The minimum time required to achieve 99 *percent* disinfection efficiency would be

(a) 9.93 *minutes* (b) 11.93 *minutes*

(c) 19.93 *minutes* (d) 21.93 *minutes*

33. A camera with a focal length of 20 *cm* fitted in an aircraft is used for taking vertical aerial photographs of a terrain. The average elevation of the terrain is 1200 *m* above mean sea level (MSL). What is the height above MSL at which an aircraft must fly in order to get the aerial photographs at a scale of 1:8000?

(a) 2600 *m* (b) 2800 *m*

(c) 3000 *m* (d) 3200 *m*

34. A flexible pavement has the following class of loads during a particular hour of the day.

i. 80 buses with 2-axles (each axle load of 40 *kN*)

ii. 160 bucks with 2-axles (front and rear axle loads of 40 *kN* and 80 *kN*, respectively)

The equivalent standard axle load repetitions for this vehicle combination as per IRC:37-2012 would be

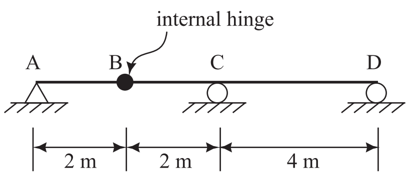
(a) 180 (b) 240 (c) 250 (d) 320

35. The inverse of the matrix $\begin{bmatrix} 2 & 3 & 4 \\ 4 & 3 & 1 \\ 1 & 2 & 4 \end{bmatrix}$ is

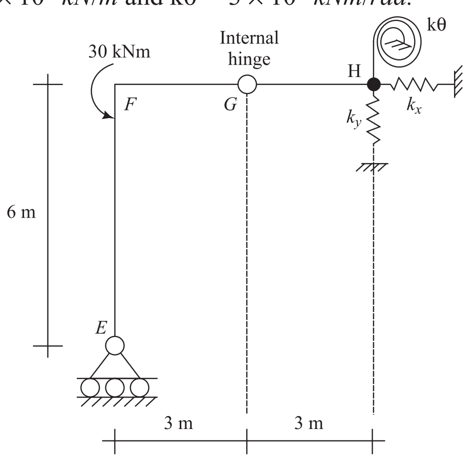
(a) $\begin{bmatrix} 10 & -4 & -9 \\ -15 & 4 & 14 \\ 5 & -1 & -6 \end{bmatrix}$ (b) $\begin{bmatrix} -10 & 4 & 9 \\ 15 & -4 & -14 \\ -5 & 1 & 6 \end{bmatrix}$

(c) $\begin{bmatrix} -2 & \frac{4}{5} & \frac{9}{5} \\ 3 & -\frac{4}{5} & -\frac{14}{5} \\ -1 & \frac{1}{5} & \frac{6}{5} \end{bmatrix}$ (d) $\begin{bmatrix} 2 & -\frac{4}{5} & -\frac{9}{5} \\ -3 & \frac{4}{5} & \frac{14}{5} \\ 1 & -\frac{1}{5} & -\frac{6}{5} \end{bmatrix}$

36. A long uniformly distributed load of 10 *kN/m* and a concentrated load of 60 *kN* are moving together on the beam ABCD shown in the figure (*not drawn to scale*). The relative positions of the two loads are not fixed. The maximum shear force (in *kN*, *round off to the nearest integer*) caused at the internal hinge B due to the two loads is __________

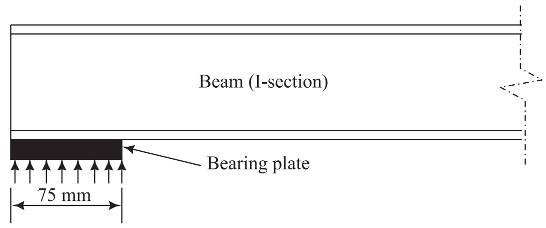


37. A plane frame shown in the figure (*not to scale*) has linear elastic springs at node H. The spring constants are $k_x = k_y = 5 \times 10^5$ *kN/m* and $k\theta = 3 \times 10^5$ *kNm/rad.*



For the externally applied moment of 30 *kNm* at node F, the rotation (in ***degrees***, *round off to* 3 *decimals*) observed in the rotational spring at node H is __________

38. A rolled *I*-section beam is supported on a 75 *mm* wide bearing plate as shown in the figure. Thicknesses of flange and web of the *I*-section are 20 *mm* and 8 *mm*, respectively. Root radius of the *I*-section is 10 *mm.* Assume: material yield stress, f_y = 250 *MPa* and partial safety factor for material, γ_{mo} = 1.10.



As per IS: 800-2007, the web bearing strength (in *kN*, *round off to 2 decimal places*) of the beam is __________

39. When a specimen of M25 concrete is loaded to a stress level of 12.5 *MPa,* a strain of 500×10^{-6} is recorded. If this load is allowed to stand for a long time, the strain increases to 1000×10^{-6}. In accordance with the provisions of IS:456-2000, considering the long-term effects, the effective modulus of elasticity of the concrete (in *MPa*) is __________

40. A water treatment plant treats 6000 m^3 of water per day. As a part of the treatment process, discrete particles are required to be settled in a clarifier. A column test indicates that an overflow rate of 1.5 *m* per hour would produce the desired removal of particles through settling in the clarifier having a depth of 3.0 *m.* The volume of the required clarifier, (in m^3, *round off to 1 decimal place*) would be __________

41. Raw municipal solid waste (MSW) collected from a city contains 70% decomposable material that can be converted to methane. The water content of the decomposable material is 35%. An elemental analysis of the decomposable material yields the following mass percent.

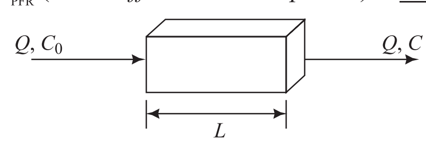
C : H : O : N : other = 44 : 6 : 43 : 0.8 : 6.2

The methane production of the decomposable material is governed by the following stoichiometric relation

$$C_aH_bO_cN_d + nH_2O \rightarrow mCH_4 + sCO_2 + dNH_3$$

Given atomic weights: C = 12, H = 1, O = 16, N = 14. The mass of methane produced (in *grams, round off to 1 decimal place*) per *kg* of raw MSW will be __________

42. Consider the reactor shown in the figure. The flow rate through the reactor is *Q* m^3/h. The concentrations (in *mg/L*) of a compound in the influent and effluent are C_0 and *C*, respectively. The compound is degraded in the reactor following the fust order reaction. The mixing condition of the reactor can be varied such that the reactor becomes either a completely mixed flow reactor (CMFR) or a plug-flow reactor (PFR). The length of the reactor can be adjusted in these two mixing conditions to L_{CMFR} and L_{PFR} while keeping the cross-section of the reactor constant. Assuming steady state and for C/C_0 = 0.8, the value of L_{CMFR}/L_{PFR} (*round off to 2 decimal places*) is __________



43. A series of perpendicular offsets taken from a curved boundary wall to a straight survey line at an interval of 6 *m* are 1.22, 1.67, 2.04, 2.34, 2.14, 1.87, and 1.15 *m*. The area (in m^2, *round off to 2 decimal places*) bounded by the survey line, curved boundary wall, the first and the last offsets, determined using Simpson's rule, is __________

44. The uniform arrival and uniform service rates observed on an approach road to a signalized intersection are 20 and 50 vehicles/minute, respectively. For this signal, the red time is 30 *s,* the effective green time is 30 *s*, and the cycle length is 60 *s*. Assuming that initially there are no vehicles in the queue, the average delay per vehicle using the approach road during a cycle length (in *s, round off to 2 decimal places*) is __________

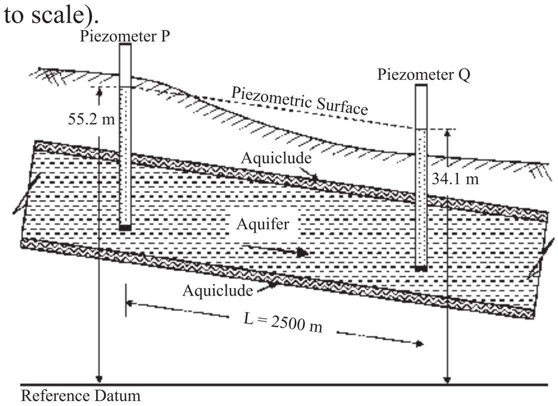
45. A broad gauge railway line passes through a horizontal curved section (radius = 875 *m*) of length 200 *m.* The allowable speed on this portion is 100 *km*/*h.* For calculating the cant, consider the gauge as centre-to-centre distance between the rail heads, equal to 1750 *mm.* The maximum permissible cant (in *mm, round off to 1 decimal place*) with respect to the centre-to-centre distance between the rail heads is __________

46. The speed-density relationship of a highway is given as

$$u = 100 - 0.5\,k$$

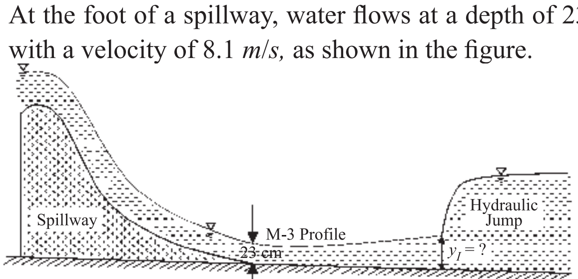
where, u = speed in *km* per hour, k = density in vehicles per *km.* The maximum flow (in vehicles per hour, *round off to the nearest integer*) is __________

47. A confined aquifer of 15 *m* constant thickness is sandwiched between two aquicludes as shown in the figure (not drawn to scale).



The heads indicated by two piezometers P and Q are 55.2 *m* and 34.1 *m,* respectively. The aquifer has a hydraulic conductivity of 80 *m*/*day* and its effective porosity is 0.25. If the distance between the piezometers is 2500 *m,* the time taken by the water to travel through the aquifer from piezometer location P to Q (in *days, round off to 1 decimal place*) is __________

48. At the foot of a spillway, water flows at a depth of 23 *cm* with a velocity of 8.1 *m*/*s,* as shown in the figure.



The flow enters as an M-3 profile in the long wide rectangular channel with bed slope = $\frac{1}{1800}$ and Manning's $n = 0.015$. A hydraulic jump is formed at a certain distance from the foot of the spillway. Assume the acceleration due to gravity, g = 9.81 m/s^2. Just before the hydraulic jump, the depth of flow y_1 (in *m*, *round off to 2 decimal places*) is __________

49. Two identical pipes (i.e., having the same length, same diameter, and same roughness) are used to withdraw water from a reservoir, in the first case, they are attached in series and discharge freely into the atmosphere, in the second case, they are attached in parallel and also discharge freely into the atmosphere. Neglecting all minor losses, and assuming that the friction factor is same in both the cases, the ratio of the discharge in the parallel arrangement to that in the series arrangement (*round off to 2 decimal places*) is __________

50. The ordinates, u, of a 2-hour unit hydrograph (*i.e., for 1 cm of effective rain*), for a catchment are shown in the table.

t (*hour*)	0	1	2	3	4	5	6	7	8	9	10	11	12
u (m^3/s)	0	2	8	18	32	45	30	19	12	7	3	1	0

A 6-hour storm occurs over the catchment such that the effective rainfall intensity is 1 *cm*/*hour* for the first two hours s, zero for the next two hours, and 0.5 *cm*/*hour* for the last two hours. If the base flow is constant at 5 m^3/s, the peak flow due to this storm (in m^3/s, *round off to 1 decimal place*) will be __________

51. The dimensions of a soil sampler are given in the table.

Parameter	Cutting edge	Sampling tube
Inside diameter (*mm*)	80	86
Outside diameter (*mm*)	100	90

For this sampler, the outside clearance ratio (in *percent, round off to 2 decimal places*) is __________

52. A 2 *m* × 4 *m* rectangular footing has to carry a uniformly distributed load of 120 *kPa.* As per the 2:1 dispersion method of stress distribution, the increment in vertical stress (in *kPa*) at a depth of 2 *m* below the footing is __________

53. Constant head permeability tests were performed on two soil specimens, *S1* and *S2.* The ratio of height of the two specimens ($L_{S1}:L_{S2}$) is 1.5, the ratio of the diameter of specimens ($D_{S1}:D_{S2}$) is 0.5, and the ratio of the constant head ($h_{si}:h_{s2}$) applied on the specimens is 2.0. If the discharge from both the specimens is equal, the ratio of the permeability of the soil specimens ($k_{S1}:k_{S2}$) is __________

54. A timber pile of length 8 *m* and diameter 0.2 *m* is driven with a 20 *kN* drop hammer, falling freely from a height of 1.5 *m.* The total penetration of the pile in the last 5 blows is 40 *mm.* Use the Engineering News Record expression. Assume a factor of safety of 6 and empirical factor (allowing reduction in the theoretical set, due to energy losses) of 2.5 *cm.* The safe load carrying capacity of the pile (in *kN, round off to 2 decimal places*) is __________

55. A square footing of 2 *m* sides rests on the surface of a homogeneous soil bed having the properties: cohesion c = 24 *kPa*, angle of internal friction ϕ = 25°, and unit weight γ = 18 kN/m^3. Terzaghi's bearing capacity factors for ϕ = 25° are N_c = 25.1, N_q = 12.7, N_γ = 9.7, N_c' = 14.8, N_q' = 5.6, and N_γ' = 3.2. The ultimate bearing capacity of the foundation (in *kPa, round off to 2 decimal places*) is __________

HINTS & SOLUTIONS

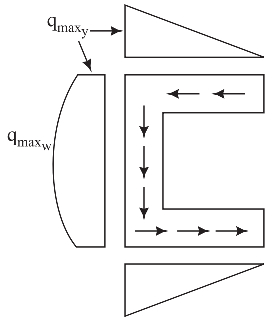
GENERAL APTITUDE TEST

1. **(c)** The word 'reach' is the correct answer. Rest of the options are eliminated because they require a preposition to follow them.
2. **(d)** The sentence talks about the growth rate of ABC Motors which is singular; correspondingly, the sentence requires 'as that of ' to match the singularity. Option (e) i.e., 'as those off' Option (a) and (c) are irrelevant as no phrase as such exists.
3. **(a)** Area to be carpet = 70 × 55 – 550 = 3300 sq. mts.
   Cost of carpeting = 3300 × 50 = 165,000.
4. **(c)** Volume of the wall occupied by bricks
   $= 30 \times 12 \times 6 \times \frac{60}{100} = 36 \times 36$
   Number of bricks used for the construction
   $= \frac{30 \times 36 \times 100 \times 100 \times 100}{8 \times 6 \times 6} = 45{,}00{,}000 = 45$ Lakhs.
5. **(b)** The article 'the' will come at the first blank because the sentence talks about a particular person. So, we will consider only option (a) and (b). The article 'a' will come at the second blank because it will take the singular word 'gold'. Therefore, the correct answer is option (b).
6. **(b)** Workers are Ram, Krishna, Amir and John. Ram and John have worked for 5 hours. Krishna does not want to work with Ram. So, in new pairing Krishna has to work with John and Ram has to work with Amir.
7. **(d)** Let population of state x is A and state y is B.
   ATQ, $\frac{A}{B} = P$ ...(i)
   and, Now population of state $x = A + \frac{Ax}{100}$
   $= A\left(\frac{100+x}{100}\right)$
   New population state $y = B\left(\frac{100+y}{100}\right)$
   Now, $P' = \frac{A\left(\frac{100+x}{100}\right)}{B\left(\frac{100+y}{100}\right)} = \frac{A(100+x)}{B(100+y)}.$
   $P' = \frac{P(100+x)}{(100+y)}$
   $\frac{P'}{P} = \frac{(100+x)}{(100+y)}$
   Percentage increase in P
   $= \left(\frac{P'-P}{P}\right) \times 100 = \frac{(100+x)-(100+y)}{(100+y)} \times 100$
   $= \frac{100(x-y)}{(100+y)}.$
8. **(d)** It can't be interred as nothing as such has been mentioned in the passage.
9. **(c)** Time required to fill the empty oil tank when all the three pipes are open
   $= \frac{1}{\frac{1}{5}+\frac{1}{4}-\frac{1}{20}} = \frac{1}{\frac{4+5-1}{20}} = \frac{20}{8} = 2.5$ hours.
10. **(b)**

TECHNICAL SECTION TEST

1. **(d)** $[4-2-6]^T = \begin{bmatrix} 4 \\ -2 \\ -6 \end{bmatrix}$
   Euclidean norms $= \sqrt{4^2 + (-2)^2 + (-6)^2} = \sqrt{56}$
2. **(a)** Laplace transform of sin $h(at) = \frac{a}{s^2 - a^2}$
3. **(d)** $\lim_{x\to 0} \frac{x \sin x}{1-\cos x}$
   Apply L-Hospital rule $\frac{x\cos x + \sin x}{\sin x}, \left(\frac{0}{0}\right)$
   Apply L-Hospital rule again
   $\lim_{x\to 0} \frac{(x(-\sin x)+\cos x)+\cos x}{\cos x} = \left(\frac{1+1}{1}\right) = 2$
4. **(d)** Curl of vector $= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ d/dx & d/dy & d/dz \\ 2x^2 & 5z^2 & -4yz \end{vmatrix}$
   $$= \hat{i}\left(\frac{d}{dy}[-4yz] - \frac{d}{dz}\left[5z^2\right]\right) - \hat{j}\left(\frac{d}{dx}(-4yz) - \frac{d}{dz}(2x^2y)\right) + \hat{K}\left(\frac{d}{dy}(5z^2) - \frac{d}{dy}(2x^2y)\right)$$
   $$= \hat{i}(-4z-10z) - \hat{j}(0) + \hat{k}(-2x^2) = -14z\hat{i} - 2x^2\hat{k}$$
5. **(c)** $\frac{\tau}{R} = \frac{T}{J}$
   $\frac{\tau}{R} = \frac{T}{2\pi R^3 t}$
   $\tau = \frac{T}{2\pi R^2 t} = \frac{T}{2Amt}, T = 2\tau Amt$
6. **(c)** Effective length for a steel column of length restrained against translation and rotation at one end is 1.2
7. **(c)** Fineness modulus of mean size 1.18 = 4
   Fineness modulus of mean size 2.36 = 5
   So, for fineness modulus 4.3,
   The mean size of particles of aggregate is b/w 118 & 236

8. (a) From Shear flow distribution for channel:



9. (a) Hydro carbons and Nitrogen oxides are considered primary pollutants based on their origin

10. (a) Alkalinity is contributed mainly by CO_3^{2-}, H^+, $HC\bar{O}_3$, $O\bar{H}$ions

11. (a) Fatigue and shear are the type of failure considered is bituminous pavement design

12. (d) The net force is zero for on object of any shape, when subjected to uniform pressure over the entire surface the force acts in all directions and hence cancel out means zero

13. (d) Velocity field $2\hat{i} + (x+y)\hat{j} + (xyz)\hat{k}$

acceleration $a_x = \dfrac{d\vec{v}}{dt}$

$$= \left[\frac{\delta v}{\delta t} + u\frac{\delta v}{\delta x} + v\frac{\delta v}{\delta y} + w\frac{\delta v}{\delta z}\right]$$

$$a_x = \left[0 + 2\times\frac{\delta}{\delta x}(2) + (x+y)\frac{\delta}{\delta y}(2) + xyz\frac{\delta(2)}{\delta z}\right]$$

Hence $a_x = 0$

$$a_y = 0 + 2\times\frac{\delta}{\delta x}(x+y) + (x+y)\frac{\delta}{\delta v}(x+y) + xyz\frac{\delta}{\delta z}(x+y)$$

$a_y = 2 + x + y$

$$a_z = 0 + 2\times\frac{\delta}{\delta x}(xyz) + (x+y)\frac{\delta}{\delta y}(xyz) + xyz\frac{\delta}{\delta z}(xy)$$

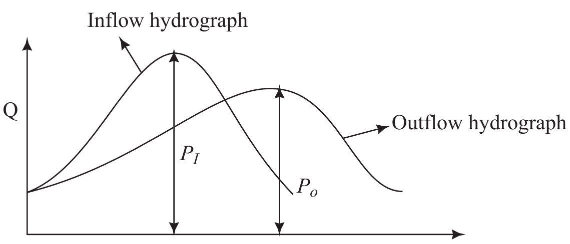
$$= 0 + 2yz + (x+y)(xz) + x^2zy^2$$

$$a = (2+x+y)\hat{j} + (2yz + x^2z + yxz + x^2y^2z^2)\hat{k}$$

At point (1, 1, 2)

$a = 4j + 10k$

14. (c)



Peak of inflow hydrograph is greater than that of out flow hydrograph due to evaporation and other losses, and the time of occurance of inflow hydrograph is more for outflow hydrograph than inflow hydrograph

Hence, $p_1 > p_o$; $t_1 < t_0$

15. (c) Taylors stability number $= \dfrac{c}{Fc\gamma H}$

16. (d) 'SC' as per Indian standard soil classification system stands for Clayey Sand

17. (a) When, $\dfrac{\delta^2 h}{\delta x^2} + \dfrac{\delta^2 h}{\delta z^2} = 0$ So, multiplied factor $= \sqrt{\dfrac{k_z}{k_x}}$

18. (d) Lagrange's form is more efficient when you have to interpolate several data sets on the same data point. Newton's form is more efficient when you have to interpolate data incrementally. So no relationship between both.

19. (c) From green shield's linear model. So, maximum flow

$$Q_{max} = \frac{v_f \times k_j}{4}$$

20. (15) Degree of static indeterminancy $= D_{si} + D_{se}$ – force release

$= 3C + (S-3) - 1 = 3\times 4 + (7-3) - 1$

$= 15$

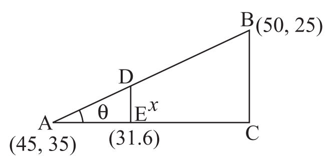
21. (46) As given that σ = 4MPa; $f_{ck} = 25$

So, $f_m = f_{ck} + 1.65\sigma$

$= 25 + 1.65 \times 4$

= 31.6 MPa

To find w/c for 31.6



So, ∠BAC, $\tan\theta = \left[\dfrac{50-45}{35-25}\right] = \dfrac{5}{10} = \dfrac{1}{2}$

now ∠DAE, $\tan\theta = \left[\dfrac{x}{34}\right] = \left[\dfrac{1}{2}\right] \Rightarrow x = 1.7$

Hence w/c ratio required 31.6 is 45 + 1.7 = 46.7%

22. (3) For a polynomial with 4 sides sum of interior angles is 360°

But ∠P + ∠Q + ∠R + ∠S = 88 + 92 + 94 + 89 = 363°

So, angular correction = –3°

Hence there is an error of +3°

23. (30) Braking distance $= \dfrac{v^2}{2g(f + 0.01n)}$

$$= \frac{10^2}{2\times 9.81(0.46 + 0.01\times 4)} = 30\text{m}$$

24. (5184) Duty $= \dfrac{8.64B}{\Delta} = \dfrac{8.64\times 120}{0.4} = 2592$

$Q = A$/Duly

Area (A) = Q × Duty = 2 × 2592 = 5184 hectares

25. (15) For 4 years

$$U_1 = \frac{s_1}{s_f}\times 100 = \frac{10}{40}\times 100 = 25\%$$

$Tv_1 = \frac{\pi}{4} \times \left(\frac{U_1}{100}\right)^2 = \frac{\pi}{4} \times \left(\frac{25}{100}\right)^2 = 0.0491$

For 9 years

$Tv_2 = \frac{c_v \times t}{d^2}$

The soil and drainage path lengths donot change hence $\frac{c_v}{d^2}$ is same as in 4 years case

$\frac{Tv_9}{Tv_4} = \frac{t_9}{t_4}$

$\frac{Tv_9}{0.0491} = \frac{9}{4} \Rightarrow Tv_9 = 0.1104$

$Tv_9 = \frac{\pi}{4} \times \left[\frac{U_2}{100}\right]^2$

$0.1104 = \frac{\pi}{4} \times \left[\frac{U_2}{100}\right]^2$

$U_2 = 37.5$

Now, The expected consolidation statement.

$\frac{s_2}{s_f} = U_2$

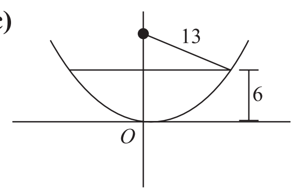
$\because S_f = 40$

$\frac{s_2}{40} = 37.5$

$s_2 = 15$mm

26. (b) Since $y > x$, then probability of a random variable b/w x and y is $\frac{1}{y-x}$

27. (c)



$x^2 + (y-13)^2 = 13^2, x^2 = 13^2 - (y-13)^2$

Volume $= \pi\int_0^6 x^2 dy = \pi\int_0^6 13^2 - (y-13)^2 dy$

$= \pi\left[\int_0^6 13^2 dy - \int_0^6 y^2 dy - \int_0^6 13^2 dy + \int_0^6 26y dy\right]$

$= \pi \times \left[26 \times \frac{6^2}{2} - \frac{6^3}{3}\right] = 396\,\pi$

28. (d) $\frac{dy}{dx}(x \ln x) = y$

$\int \frac{dy}{y} = \int \frac{dx}{x \ln x}$

take $\ln x = s$

differentiating both sides

$\frac{1}{x} = \frac{ds}{dx}$

$dx = ds \times x$

now $\int \frac{dy}{y} = \int \frac{dx}{x \times s} = \int \frac{ds \times x}{x \times s} = \int \frac{dy}{y} = \int \frac{ds}{s}$

$\ln y = \ln s + \ln k$

$y = ks$

$y = k \ln x$

29. (c) $\sigma_x = 80$ MPa

$\sigma_y = -20$ MPa

$\tau_{xy} = -25$ MPa

$\tan 2\theta = \frac{2\tau_{xy}}{\sigma_x - \sigma_y} = \frac{2 \times (-25)}{80 + 20}$

$\theta = -13.28°$

Angle of maximum shear stress = $\theta + 45°$

$= 45° - 13.28° = 31.7°$

30. (b) As given that

$f_y = 250$ MPa

$f_b = 1000$ MPa

As we know that,

Slenderness rates $\lambda = \sqrt{\frac{f_y}{f_b}} = \sqrt{\frac{250}{1000}} = \sqrt{1/4} = 1/2$

31. (a) As per IS 456.2000, an entrained air percentage of 4 ± 1 or 5 ± 1 is used to resize freezing and thawing conditions hence the first assertion is wrong,

Equivalent alkali content [Na_2O]

$= [Na_2O] + 0.655\,[k_2O] = 1.41\%$

Hence 2nd assertion is true

32. (c) **Case I:**

Disinfection efficiency $D_1 = 1 - \bar{e}^{kt_1}$

$0.5 = 1 - \bar{e}^{kt}$ at $t = 3$ minutes

$0.5 = 1 - e^{-3k}$

$e^{-3k} = 0.5$

$\ln(e^{-3k}) = ln\,(0.5)$

$-3k = ln\,(0.5)$

Hence $k = 0.231$/minute

Case II:

$D_2 = 1 - e^{-kt_2}$

$0.99 = 1 - e^{-0.231t_2}$

$e^{-0.231t_2} = 0.01$

$\ln(e^{-0.231t_2}) = \ln\left(\frac{1}{100}\right)$

$(-0.231)\,t_2 = (-4.60)$

$t_2 = 20$ minutes

33. (b) $s = \frac{f}{H - h}$

Here s =1:8000, h = 1200 m, f =20 cm

So, $\frac{1}{8000}=\frac{0.2}{H-1200}$

$H-1200=\frac{8000\times 2}{10}$

H = 2800 m

34. (a) ESA = $80\times\left(\frac{40}{80}\right)^4+80\times\left(\frac{40}{80}\right)^4+160\times\left(\frac{40}{80}\right)^4+160\times\left(\frac{80}{80}\right)^4$

$=80\times\frac{1}{16}+80\times\frac{1}{16}+160x\frac{1}{16}+160 = 180$

35. (c) As given matrix

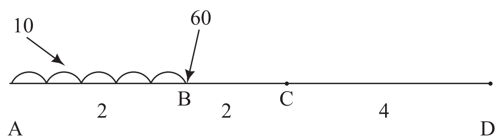
$$A=\begin{bmatrix}2 & 3 & 4\\ 4 & 3 & 1\\ 1 & 2 & 4\end{bmatrix}$$

As we know that

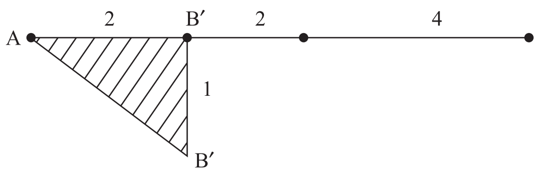
$A^{-1}A = I$

So, Only option (c) is satisfied.

36. (70)



ILD for SF_B

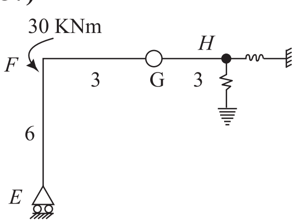


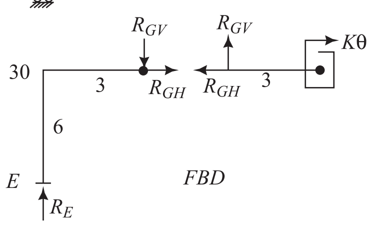
By muller-breslau principle

Maximum × *SF* at *B* =10 × area of *ABB*′ + 60 × *BB*′

$= 10\times\left[\frac{1}{2}\times 2\times 1\right]+60\times[1] = 70$ kN

37. (0.0057)





But, $R_{GH}-R_{GH}=0$

(1) $R_{GV}\times 3 = 30$

(2) $R_{GV}\times 3 = K_\theta\times\theta$

$30 = K_\theta\times\theta$

$\theta = 30/3\times 10^{-5} = 10^{-4}\text{ rad} = \frac{10^{-4}\times 180}{\pi} = 0.0057$

38. (272.732)

F_y (Web bearing strength) = $Ag\times\frac{Fy}{\nu_{mo}}$

[F_y = 250 MPa]

$\nu_{mo} = 1.1 = \frac{250}{1.1}$ MPa

width of critical section at root resisting web crippling due to high bearing stress

$w_l = \left[b+2.5(t_f+R)\right]t_w$

$=[75+2.5(20+10)]8 = 1200\text{ mm}^2$

Web bearing strength = $\frac{1200\times 250}{1.1}$

= 272732 N = 272.732 kN

39. (12500)

Effective modulus of elastic due to deep = $\frac{E_C}{1+\theta}$

$E_C = 5000\sqrt{f_{ck}}$

$=5000\times\sqrt{25} = 25\times 10^4$ MPa

Creep coefficient (θ)

$=\left[\frac{\text{longterm strain}-\text{elastic strain}}{\text{elastic strain}}\right]$

$=\frac{(1000-500)\times 10^{-6}}{500\times 10^{-6}}=1$

So, $E_C=\frac{25\times 10^4}{2}=12.5\times 10^4$ MPa =12500 Mpa

40. (500)

Q = 6000 m^3/day

V = 1.5 m/hr

= 1.5 × 24 m/day =36 m/day

$VA = Q$

So, Area $A = Q/V = \frac{6000}{36} = 166.67\text{ m}^2$

Volume of classifier = Area × depth

= 166.67 × 3 = 500.01 m^3

41. (151.8)

$C_aH_bO_cN_d + nH_2O \rightarrow mCH_4 + SCO_2 + dNH_3$

But C:H: O : N = 44:6 : 43 : 0.8

i.e. a = 44, b = 6, c = 43, d = 0.8

From eqn.

For carbon $m + s = 44 = a$ …(i)

For hydrogen $4m - 2n = 6 = b$ …(ii)

For oxygen $2s - n = 43 = c$ …(iii)

Solving

$4m - 2(-43 + 25) = 6$

$4m - 4s = 6 - 86$

$4m - 4s = -80$

$m - s = 20$ ...(iv)

Solving (i) to (iv)

$m = 11.7$

Molecular height of $C_aH_bO_cN_d$

$= 44 \times 12 + 6 \times 1 + 43 \times 16 + 0.8 \times 14 = 1233.2$ g

Molecular height of m CH_4 $= 11.7 \times 16 = 187.2$g

i.e., 1233.2 g of $C_aH_bO_cN_d$ produces 187.2 g Part of CH_4 gas

1 g of $C_aH_bO_cN_d$ produce $= \dfrac{187.2}{1233.2}$

= 0.15180 g of methane

Than 1 kg produces 0.1518 kg of methane = 151.8 gm.

42. (1.1211)

For plug flow $C = C_o e^{kt_1}$ ...(i)

Where C_o is the concentration of influent and C the concentration effluent

Rearranging (i) $C_o = \dfrac{C}{e^{-kt_1}}$ $\left[\because \dfrac{c}{co} = 0.8\right]$

As per given *eq*

$0.8 = e^{-kt_1}$

$\ln 0.8 = -kt_1$

$Kt_1 = 0.223$ ...(ii)

Where $t_1 = \dfrac{A \times L \text{ plug flow}}{Q}$

For complete mix

$C_O = C[1 + kt_2]$ ...(iii)

$0.8 = \dfrac{1}{1 + kt_2}$

$kt_2 = 0.25$ ...(iv)

Where $t_2 = \dfrac{A \times L \text{ complete mix}}{Q}$

From (2) to (4)

$\dfrac{Kt_1}{Kt_2} = \dfrac{0.223}{0.25} = 0.892$

$\dfrac{A_L \text{ plug}}{A_L \text{ complete}} = 0.892$

or $\dfrac{A_L \text{ complete}}{A_L \text{ plug}} = \dfrac{1}{0.892} = 1.1211$

43. (68.5)

By Simpson's rule

$$A = \frac{d}{3}[(\text{first} + \text{last}) + 4(\text{odd}) + 2(\text{even})]$$

$$\text{Area} = \frac{d}{3}[(ho + h_6) + 4(h_1 + h_3 + h_5) + 2(h_2 + h_4)]$$

Here $x = 6$

$h_0 = 1.22$	$h_3 = 2.34$
$h_1 = 1.67$	$h_4 = 2.14$
$h_2 = 2.04$	$h_5 = 1.87$
$h_6 = 1.15$	

$$A = \frac{6}{3}[(1.22 + 1.15) + 4(1.67 + 2.34 + 1.87) + 2(2.04 + 2.14)]$$

$= 68.5$ m^2

44. (12.5)

$$\text{Average delay per vehicle} = \frac{C[1 - g/C]^2}{2[1 - V/S]}$$

$g = 30$, $C = 60$, $V = 20$, $S = 50$

$$\frac{60\left[1 - \frac{30}{60}\right]^2}{2 \times \left[1 - \frac{20}{50}\right]} = \frac{30 \times \frac{1}{4}}{1 - \frac{2}{5}} = 12.5 \text{ seconds}$$

45. (0.15748)

As we know that,

$$\text{Allowable cant } (e) = \frac{GV^2}{127R}$$

[$\because G = 1750$ mm, $V = 100$ kmph, $R = 875$ m given]

$$= \frac{1.75 \times 100 \times 100}{127 \times 875} = 0.15748 \text{ m}$$

46. (5000)

As given that, $u = 100 - 0.5$ K

$q = K_u$

$q = 100K - 0.5K^2$

$\dfrac{dq}{dk} = 100 - 1k$

For minimum capacity $\left[\dfrac{dq}{dk}\right] = 0$

$100 - 1K = 0$

$\Rightarrow 100 = K$

Now $q_{min} = 100 \times 100 - 0.5 \times 100^2$

= 5000 vehicles/hr

47. (925.65)

$h_2 = 55.2$, $n = 0.25$, k = 80m/day

$h_1 = 34.1$, $L = 2500$ m

$\Delta h = 55.2 - 34.1 = 21.1$ m

$$\text{Time } (t) = \frac{\text{Length}}{\text{seepage velocity } (v_s)}$$

$$V_S = \frac{v}{n} = \left[\frac{k \times \frac{\Delta h}{L}}{n}\right]$$

$$= \left[\frac{80 \times 21.1}{2500 \times 0.25}\right] = 2.7008 \text{ m/day}$$

$$\text{Time taken } (t) = \left[\frac{L}{Vs}\right] = \frac{2500}{2.7008} = 925.65 \text{ days}$$

48. (0.417)

From Manning's eqn.

$$Q = \frac{1}{n} R^{2/3} S^{1/2} \times A \quad \ldots(1)$$

where, n = 0.015, S = 1/1800, $R = y$ = 0.23m (rectangular wide channel)

$Q = q.B$

Now eqn. (1) becomes

$$q.B = \frac{1}{n} y^{2/3} S^{1/2} \times y \times B$$

[∵For wide channel R = y]

$$q = \frac{1}{0.015} \times \left(\frac{1}{1800}\right)^{1/2} \times y^{5/3}$$

But $q = y \times v$

q = 8.1 × 0.23 = 1.863 m^3/sec/m

1.863 = 1.5713 $y^{5/3}$

y = 1.1075=1.11

For wide rectangular channel $y_c = \left(\frac{q^2}{g}\right)^{1/3}$

$$y_c = \left(\frac{(1.863)^2}{9.81}\right)^{1/3} = 0.707\text{m}$$

Again for hydraulic jump

$$\frac{y_1}{y_2} = \frac{1}{2}\left[\sqrt{1+8Fr^2} - 1\right]$$

$$F_2 = \sqrt{\frac{q^2}{gy_c^3}} = \sqrt{\frac{1.863^2}{9.81 \times 1.11^3}} = 0.508$$

$$\frac{y_1}{y_2} = \frac{1}{2}\left[\sqrt{1+8F_2^2} - 1\right]$$

$$\frac{y_1}{y} = \frac{1}{2}\left[\sqrt{1+8\times 0.508^2} - 1\right]$$

y_1 = 0.417 m < y_c

$y_1 < y_c$, hence supercritical

49. (2.828) In series connection or end to end to end connection

$$h = \frac{flv^2}{2gd}, \left[\begin{array}{l}\text{here } l = 2l \\ v = \dfrac{Q}{\pi/4\, d^2}\end{array}\right]$$

$$\text{Hence, } h = \left[\frac{f \times 2l \times Q_{\text{series}}^2}{12d^5}\right] \quad \ldots(1)$$

For parallel connection $Q = \frac{Q_{\text{parallel}}}{2}$

$$h = \frac{f \times l \times v^2}{2gd}, \left[\begin{array}{l}\text{here } l = l \\ V = \dfrac{\frac{Q_{\text{parallel}}}{2}}{\pi/4d^2}\end{array}\right]$$

$$\text{Hence, } h = \frac{f \times l \times (Q\ \text{parallel}/2)^2}{12d^5} \quad \ldots(2)$$

But head loss is same in both series and parallel connection, equating eq. (1) and (2)

$$\frac{f \times 2l \times Q_{\text{series}}^2}{12d^5} = \frac{f \times l \times \left(\frac{Q\ \text{parallel}}{2}\right)^2}{12d^5}$$

$$\left[\frac{Q_{\text{parallel}}}{Q_{\text{series}}}\right] = \sqrt{8} = 2\sqrt{2} = 2.828$$

50. (97)

Total rainfall in first 2 hrs. — 2 cm

Total rainfall in 2 – 4 hrs — 0 cm

Total rainfall in 4 – 6 hrs — 0.5 × 2 = 1 cm

Time (hour) (1)	(U) m^3/sec (2)	Ist DRH 2cm × (2) (3)	IInd DRH 0 cm × (2) legged by 2hrs (4)	IIIrd DRH 1 cm × (2) legged by 1 hr (5)	Sum Ordinate of 6 hrs Total complex DRH (6)
0	0	0	_	_	0
1	2	4	_	_	4
2	8	16	0	_	16
3	18	36	0	_	36
4	32	64	0	0	64
5	45	90	0	2	92
6	30	60	0	8	68

Time (hour) (1)	(U) m^3/sec (2)	I^{st} DRH 2cm × (2) (3)	II^{nd} DRH 0 cm × (2) legged by 2hrs (4)	III^{rd} DRH 1 cm × (2) legged by 1 hr (5)	Sum Ordinate of 6 hrs Total complex DRH (6)
7	19	38	0	18	56
8	12	24	0	32	56
9	7	14	0	45	59
10	3	6	0	30	36
11	1	2	0	19	21
12	0	0	0	12	12

Max/peak ordinate of DRH is 92 cm^3/s

Max flood discharge = Peak + Base flow

$= 92 + 5 = 97\ m^3/s$

51. **(11.11)** Outside clearance ratio $= \frac{D_2 - D_1}{D_1} \times 100$

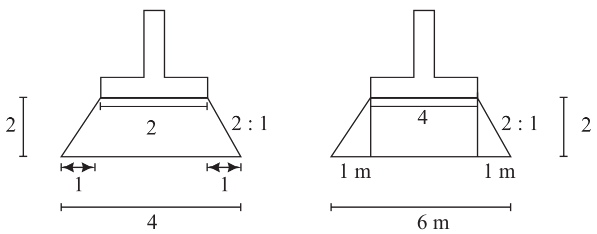
$D_2 = 100$ mm

$D_1 = 90$ mm

$= \frac{100-90}{90} \times 100$

$= 11.11\%$

52. **(40)**



$\Delta p = \frac{p \times A}{4 \times 6} = \frac{120 \times 2 \times 4}{4 \times 6} = 40$ kPa

53. **(3)** $Q = kiA$

$= k \times \frac{h}{L} \times A$

$Q_1 = \frac{k_{s_1} h_{s_1}}{L_{s_1}} \times d_{s_1}^2$

$Q_2 = \frac{k_{s_2} \times h_s}{L_{s_2}} \times d_{s_2}^2$

$\because \frac{Q_1}{Q_2} = 1$

$Q_1 = Q_2$

Thus, $\frac{ks_1 \times hs_1 \times d_{s_1}^2}{Ls_1} = \frac{ks_2 \times hs_2 \times d_{s2}^2}{Ls_2}$

$$\frac{k_{s_1}}{k_{s_2}} = \frac{\left[\frac{h_{s_2}}{h_{s_1}}\right] \times \left[\frac{d_{s_2}}{d_{s_1}}\right]^2}{\left[\frac{Ls_2}{Ls_1}\right]} = \frac{\frac{1}{2} \times \left(\frac{1}{0.5}\right)^2}{\left(\frac{1}{1.5}\right)} = 3$$

54. **(151.5)**

As we know that

Engineering news record expression

$Q_S = \frac{wh}{F(s+c)}$

$W = 20$ kN, $h = 1.5$ m, $C = 2.5$ cm, $F = 6$

$S = \frac{40}{5} = 8$ mm

Hence, $Q_S = \frac{20 \times 1.5}{6\left[8 \times 10^{-3} + 2.5 \times 10^{-2}\right]}$

$= 151.511$ kN

55. **(353.92)**

$Q_u = 1.3\ C'N'_C + qN'q + 0.4B\ \gamma\ N'\ \gamma$

And, $C' = C \times \frac{2}{3} = \frac{2}{3} \times 24 = 16$ kPa $[\because C = 24 \text{ given}]$

Since $\phi = 25 < 29°$, hence local shear failure occurs

Now $Q_u = 1.3 \times 16 \times 14.8 + 0 + 0.4 \times 18 \times 2 \times 3.2$

$= 307.842 + 46.08 = 353.922$ kPa

GATE CIVIL ENGINEERING SOLVED PAPER

2018 Set-1

Duration: 3 hrs **Maximum Marks: 100**

INSTRUCTIONS

1. There are a total of 65 questions carrying 100 marks.

2. The subject specific GATE paper section consists of 55 questions. The GA section consists of 10 questions.

3. Questions are of Multiple Choice Question (MCQ) or Numerical Answer type. A multiple choice question will have four choices for the answer with only one correct choice. For numerical answer type questions, the answer is a number and no choices will be given.

4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions will result in NEGATIVE marks. For all 1 mark questions, $\frac{1}{3}$ mark will be deducted for each wrong answer. For all 2 marks questions, $\frac{2}{3}$ mark will be deducted for each wrong answer.

5. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE.**

GENERAL APTITUDE TEST

QUESTION 1 TO 25 CARRY ONE MARK EACH

1. "The driver applied the _______ as soon as she approached the hotel where she wanted to take a ________".
The words that best fill the blanks in the above sentence are
(a) brake, break (b) break, break
(c) brake, brake (d) break, brake

2. "It is no surprise that every society has had codes of behaviour; however, the nature of these codes is often _________".
The word that best fills the blank in the above sentence is
(a) unpredictable (b) simple
(c) expected (d) strict

3. Hema's age is 5 years more than twice Hari's age. Suresh's age is 13 years less than 10 times Hari's age. If Suresh is 3 times as old as Hema, how old is Hema?
(a) 14 (b) 17
(c) 18 (d) 19

4. Tower A is 90 m tall and tower B is 140 m tall. They are 100 m apart. A horizontal skywalk connects the floors at 70 m in both the towers. If a taut rope connects the top of tower A to the bottom of tower B, at what distance (in meters) from tower A will the rope intersect the skywalk?
(a) 22.22 (b) 50
(c) 57.87 (d) 77.78

5. The temperature T in a room varies as a function of the outside temperature T_0 and the number of persons in the room p, according to the relation $T = K(\theta p + T_0)$, where θ and K are constants. What would be the value of θ given the following data?

T_0	p	T
25	2	32.4
30	5	42.0

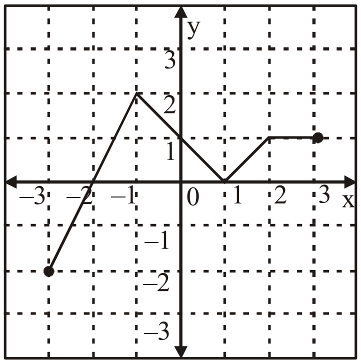
(a) 0.8 (b) 1.0
(c) 2.0 (d) 10.0

QUESTION 6 TO 10 CARRY TWO MARKS EACH

6. A fruit seller sold a basket of fruits at 12.5% loss. Had he sold it for ₹ 108 more, he would have made a 10% gain. What is the loss in Rupees incurred by the fruit seller?
(a) 48 (b) 52
(c) 60 (d) 108

7. The price of a wire made of a superalloy material is proportional to the square of its length. The price of 10 m length of the wire is ₹ 1600. What would be the total price (in ₹) of two wires of lengths 4 m and 6m?
(a) 768 (b) 832
(c) 1440 (d) 1600

8. Which of the following function(s) is an accurate description of the graph for the range(s) indicated?



(i) $y = 2x + 4$ for $-3 \leq x \leq -1$
(ii) $y = |x - 1|$ for $-1 \leq x \leq 2$
(iii) $y = ||x| - 1|$ for $-1 \leq x \leq 2$
(iv) $y = 1$ for $2 \leq x \leq 3$
(a) (i), (ii) and (iii) only.
(b) (i), (ii) and (iv) only.
(c) (i) and (iv) only.
(d) (ii) and (iv) only

9. Consider a sequence of numbers $a_1, a_2, a_3, ..., a_n$ where $a_n = \frac{1}{n} - \frac{1}{n+2}$, for each integer $n > 0$. What is the sum of the first 50 terms?

(a) $\left(1+\frac{1}{2}\right) - \frac{1}{50}$

(b) $\left(1+\frac{1}{2}\right) + \frac{1}{50}$

(c) $\left(1+\frac{1}{2}\right) - \left(\frac{1}{51}+\frac{1}{52}\right)$

(d) $1 - \left(\frac{1}{51}+\frac{1}{52}\right)$

10. Each of the letters arranged as below represents a unique integer from 1 to 9. The letters are positioned in the figure such that $(A \times B \times C)$, $(B \times G \times E)$ and $(D \times E \times F)$ are equal. Which integer among the following choices cannot be represented by the letters A, B, C, D, E, F or G?

A		D
B	G	E
C		F

(a) 4 (b) 5
(c) 6 (d) 9

TECHNICAL SECTION TEST

QUESTION 1 TO 25 CARRY ONE MARK EACH

1. Which one of the following matrices is singular?

(a) $\begin{bmatrix} 2 & 5 \\ 1 & 3 \end{bmatrix}$ (b) $\begin{bmatrix} 3 & 2 \\ 2 & 3 \end{bmatrix}$

(c) $\begin{bmatrix} 2 & 4 \\ 3 & 6 \end{bmatrix}$ (d) $\begin{bmatrix} 4 & 3 \\ 6 & 2 \end{bmatrix}$

2. For the given orthogonal matrix Q,

$$Q = \begin{bmatrix} 3/7 & 2/7 & 6/7 \\ -6/7 & 3/7 & 2/7 \\ 2/7 & 6/7 & -3/7 \end{bmatrix}$$

The inverse is

(a) $\begin{bmatrix} 3/7 & 2/7 & 6/7 \\ -6/7 & 3/7 & 2/7 \\ 2/7 & 6/7 & -3/7 \end{bmatrix}$

(b) $\begin{bmatrix} -3/7 & -2/7 & -6/7 \\ 6/7 & -3/7 & -2/7 \\ -2/7 & -6/7 & 3/7 \end{bmatrix}$

(c) $\begin{bmatrix} 3/7 & -6/7 & 2/7 \\ 2/7 & 3/7 & 6/7 \\ 6/7 & 2/7 & -3/7 \end{bmatrix}$

(d) $\begin{bmatrix} -3/7 & 6/7 & -2/7 \\ -2/7 & -3/7 & -6/7 \\ -6/7 & -2/7 & 3/7 \end{bmatrix}$

3. At the point $x = 0$, the function $f(x) = x^3$ has
(a) local maximum
(b) local minimum
(c) both local maximum and minimum
(d) neither local maximum nor local minimum

4. A column of height h with a rectangular cross-section of size $a \times 2a$ has a buckling load of P. If the cross-section is

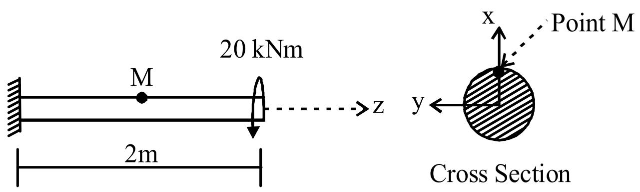
changed to 0.5 a × 3a and its height changed to 1.5h, the buckling load of the redesigned column will be
(a) P/12 (b) P/4
(c) P/2 (d) 3P/4

5. A steel column of ISHB 350 @72.4 kg/m is subjected to a factored axial compressive load of 2000 kN. The load is transferred to a concrete pedestal of grade M20 through a square base plate. Consider bearing strength of concrete as 0.45 fck, where fck is the characteristic strength of concrete. Using limit state method and neglecting the self weight of base plate and steel column, the length of a side of the base plate to be provided is
(a) 39 cm (b) 42 cm
(c) 45 cm (d) 48 cm

6. The Le Chatelier apparatus is used to determine
(a) compressive strength of cement
(b) fineness of cement
(c) setting time of cement
(d) soundness of cement

7. The deformation in concrete due to sustained loading is
(a) creep (b) hydration
(c) segregation (d) shrinkage

8. A solid circular beam with radius of 0.25 m and length of 2 m is subjected to a twisting moment of 20 kNm about the z-axis at the free end, which is the only load acting as shown in the figure. The shear stress component τ_{xy} at Point 'M' in the cross-section of the beam at a distance of 1 m from the fixed end is



Cross Section

(a) 0.0 MPa (b) 0.51 MPa
(c) 0.815 MPa (d) 2.0 MPa

9. Two rectangular under-reinforced concrete beam sections X and Y are similar in all aspects except that the longitudinal compression reinforcement in section Y is 10% more. Which one of the following is the correct statement?
(a) Section X has less flexural strength and is less ductile than section Y
(b) Section X has less flexural strength but is more ductile than section Y
(c) Sections X and Y have equal flexural strength but different ductility
(d) Sections X and Y have equal flexural strength and ductility

10. The percent reduction in the bearing capacity of a strip footing resting on sand under flooding condition (water level at the base of the footing) when compared to the situation where the water level is at a depth much greater than the width of footing, is approximately
(a) 0 (b) 25
(c) 50 (d) 100

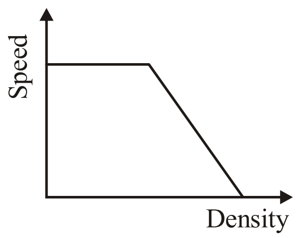
11. The width of a square footing and the diameter of a circular footing are equal. If both the footings are placed on the surface of sandy soil, the ratio of the ultimate bearing capacity of circular footing to that of square footing will be
(a) 4/3 (b) 1
(c) 3/4 (d) 2/3

12. Bernoulli's equation is applicable for
(a) viscous and compressible fluid flow
(b) inviscid and compressible fluid flow
(c) inviscid and incompressible fluid flow
(d) viscous and incompressible fluid flow

13. There are 20,000 vehicles operating in a city with an average annual travel of 12,000 km per vehicle. The NOx emission rate is 2.0 g/km per vehicle. The total annual release of NOx will be
(a) 4,80,000 kg (b) 4,800 kg
(c) 480 kg (d) 48 kg

14. A bitumen sample has been graded as VG30 as per IS : 73-2013. The '30' in the grade means that
(a) penetration of bitumen at 25°C is between 20 and 40
(b) viscosity of bitumen at 60°C is between 2400 and 3600 Poise
(c) ductility of bitumen at 27°C is more than 30 cm
(d) elastic recovery of bitumen at 15°C is more than 30%

15. The speed-density relationship for a road section is shown in the figure.



The shape of the flow-density relationship is
(a) piecewise linear
(b) parabolic
(c) initially linear then parabolic
(d) initially parabolic then linear

16. A well-designed signalized intersection is one in which the
(a) crossing conflicts are increased
(b) total delay is minimized
(c) cycle time is equal to the sum of red and green times in all phases
(d) cycle time is equal to the sum of red and yellow times in all phases

17. A flow field is given by $u = y^2$, $v = -xy$, $w = 0$. Value of the z-component of the angular velocity (in radians per unit time, up to two decimal places) at the point (0, –1, 1) is ______

18. The frequency distribution of the compressive strength of 20 concrete cube specimens is given in the table.

f (MPa)	Number of specimens with compressive strength equal to f
23	4
28	2
22.5	5
31	5
29	4

If μ is the mean strength of the specimens and σ is the standard deviation, the number of specimens (out of 20) with compressive strength less than $\mu - 3\sigma$ is ______

19. In a fillet weld, the direct shear stress and bending tensile stress are 50 MPa and 150 MPa, respectively. As per IS 800 : 2007, the equivalent stress (in MPa, up to two decimal places) will be ______

20. In a shrinkage limit test, the volume and mass of a dry soil pat are found to be 50 cm^3 and 88 g, respectively. The specific gravity of the soil solids is 2.71 and the density of water is 1 g/cc. The shrinkage limit (in %, up to two decimal places) is ______

21. A core cutter of 130 mm height has inner and outer diameters of 100 mm and 106 mm, respectively. The area ratio of the core cutter (in %, up to two decimal places) is ______

22. A 1:50 model of a spillway is to be tested in the laboratory. The discharge in the prototype spillway is 1000 m^3/s. The corresponding discharge (in m^3/s, up to two decimal places) to be maintained in the model, neglecting variation in acceleration due to gravity, is ______

23. A 10 m wide rectangular channel carries a discharge of 20 m^3/s under critical condition. Using = 9.81 m/s^2, the specific energy (in m, up to two decimal places) is ______

24. For routing of flood in a given channel using the Muskingum method, two of the routing coefficients are estimated as $C_0 = -0.25$ and $C_1 = 0.55$. The value of the third coefficient C_2 would be ______

25. A city generates 40×10^6 kg of municipal solid waste (MSW) per year, out of which only 10% is recovered/recycled and the rest goes to landfill. The landfill has a single lift of 3 m height and is compacted to a density of 550 kg/m^3. If 80% of the landfill is assumed to be MSW, the landfill area (in m^2, up to one decimal place) required would be ______

QUESTION 26 TO 55 CARRY TWO MARKS EACH

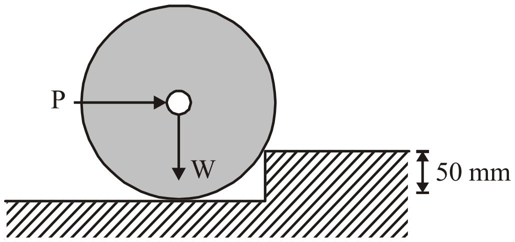
26. The value of the integral $\int_0^{\pi} x \cos^2 x \, dx$ is

(a) $\pi^2/8$ (b) $\pi^2/4$
(c) $\pi^2/2$ (d) π^2

27. A cantilever beam of length 2 m with a square section of side length 0.1 m is loaded vertically at the free end. The vertical displacement at the free end is 5 mm. The beam is made of steel with Young's modulus of 2.0×10^{11} N/m^2. The maximum bending stress at the fixed end of the cantilever is

(a) 20.0 MPa (b) 37.5 MPa
(c) 60.0 MPa (d) 75.0 MPa

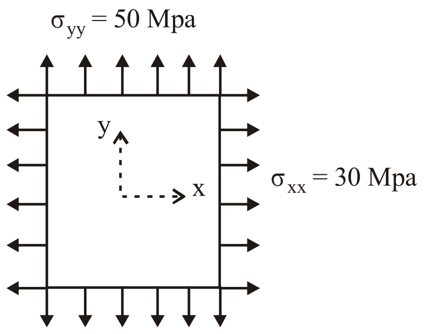
28. A cylinder of radius 250 mm and weight, W = 10 kN is rolled up an obstacle of height 50 mm by applying a horizontal force P at its centre as shown in the figure.



All interfaces are assumed frictionless. The minimum value of P is

(a) 4.5 kN (b) 5.0 kN
(c) 6.0 kN (d) 7.5 kN

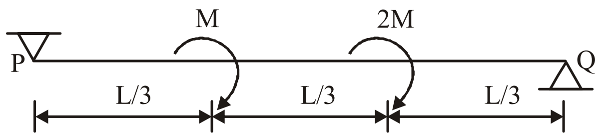
29. A plate in equilibrium is subjected to uniform stresses along its edges with magnitude $\sigma_{xx} = 30$ MPa and $\sigma_{yy} = 50$ MPa as shown in the figure.



The Young's modulus of the material is 2×10^{11} N/m^2 and the Poisson's ratio is 0.3. If σ_{zz} is negligibly small and assumed to be zero, then the strain ε_{zz} is

(a) -120×10^{-6} (b) -60×10^{-6}
(c) 0.0 (d) 120×10^{-6}

30. The figure shows a simply supported beam PQ of uniform flexural rigidity EI carrying two moments M and 2M.



The slope at P will be
(a) 0 (b) ML/(9EI)
(c) ML/(6EI) (d) ML/(3EI)

31. A 0.5 m × 0.5 m square concrete pile is to be driven in a homogeneous clayey soil having undrained shear strength, Cu = 50 kPa and unit weight, $\gamma = 18.0$ kN/m^3. The design capacity of the pile is 500 kN. The adhesion factor d is given as 0.75. The length of the pile required for the above design load with a factor of safety of 2.0 is
(a) 5.2m (b) 5.8m
(c) 11.8m (d) 12.5m

32. A closed tank contains 0.5 m thick layer of mercury (specific gravity = 13.6) at the bottom. A 2.0 m thick layer of water lies above the mercury layer. A 3.0 m thick layer of oil (specific gravity = 0.6) lies above the water layer. The space above the oil layer contains air under pressure. The gauge pressure at the bottom of the tank is 196.2 kN/m^2. The density of water is 1000 kg/m^3 and the acceleration due to gravity is 9.81 m/s^2. The value of pressure in the air space is
(a) 92.214 kN/m^2 (b) 95.644 kN/m^2
(c) 98.922 kN/m^2 (d) 99.321 kN/m^2

33. A rapid sand filter comprising a number of filter beds is required to produce 99 MLD of potable water. Consider water loss during backwashing as 5%, rate of filtration as 6.0 m/h and length to width ratio of filter bed as 1.35. The width of each filter bed is to be kept equal to 5.2 m. One additional filter bed is to be provided to take care of break-down, repair and maintenance. The total number of filter beds required will be
(a) 19 (b) 20
(c) 21 (d) 22

34. A priority intersection has a single-lane one-way traffic road crossing an undivided two-lane two-way traffic road. The traffic stream speed on the single-lane road is 20 kmph and the speed on the two-lane road is 50 kmph. The perception-reaction time is 2.5 s, coefficient of longitudinal friction is 0.38 and acceleration due to gravity is 9.81 m/s^2. A clear sight triangle has to be ensured at this intersection. The minimum lengths of the sides of the sight triangle along the two-lane road and the single-lane road, respectively will be
(a) 50 m and 20 m (b) 61 m and 18 m
(c) 111 m and 15 m (d) 122 m and 36 m

35. The following details refer to a closed traverse:

Line	Consecutive coordinate			
	Northing (m)	Southing (m)	Easting (m)	Westing (m)
PQ	----	437	173	----
QR	101	----	558	----
RS	419	----	----	96
SP	----	83	----	634

The length and direction (whole circle bearing) of closure, respectively are
(a) 1 m and 90° (b) 2 m and 90°
(c) 1 m and 270° (d) 2 m and 270°

36. A square area (on the surface of the earth) with side 100 m and uniform height, appears as 1 cm^2 on a vertical aerial photograph. The topographic map shows that a contour of 650 m passes through the area. If focal length of the camera lens is 150 mm, the height from which the aerial photograph was taken, is
(a) 800m (b) 1500m
(c) 2150m (d) 3150m

37. The solution at x = 1, t = 1 of the partial differential equation $\frac{\partial^2 u}{\partial x^2} = 25\frac{\partial^2 u}{\partial t^2}$ subject to initial conditions of u (0) = 3x and $\frac{\partial u}{\partial t}(0) = 3$ is __________
(a) 1 (b) 2
(c) 4 (d) 6

38. The solution (up to three decimal places) at x = 1of the differential equation $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} + y = 0$ subject to boundary conditions y(0) = 1 and $\frac{dy}{dx}(0) = -1$ is ______

39. Variation of water depth (y) in a gradually varied open channel flow is given by the first order differential equation

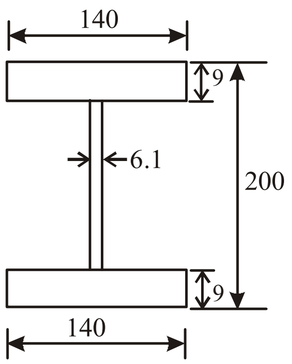
$$\frac{dy}{dx} = \frac{1 - e^{-\frac{10}{3}\ln(y)}}{250 - 45e^{-3\ln(y)}}$$

Given initial condition: y(x = 0) = 0.8 m. The depth (in m, up to three decimal places) of flow at a downstream section at = 1 m from one calculation step of Single Step Euler Method is ______

40. An RCC short column (with lateral ties) of rectangular cross section of 250 mm × 300 mm is reinforced with four numbers of 16 mm diameter longitudinal bars. The grades of steel and concrete are Fe415 and M20, respectively. Neglect eccentricity effect. Considering limit state of collapse in compression (IS 456 : 2000), the axial load carrying capacity of the column (in kN, up to one decimal place), is ______

41. An RCC beam of rectangular cross section has factored shear of 200 kN at its critical section. Its width is 250 mm and effective depth d is 350 mm. Assume design shear strength τ_c of concrete as 0.62 N/mm^2 and maximum allowable shear stress $\tau_{c,max}$ in concrete as 2.8 N/mm^2. If two legged 10 mm diameter vertical stirrups of Fe250 grade steel are used, then the required spacing (in cm, up to one decimal place) as per limit state method will be ______

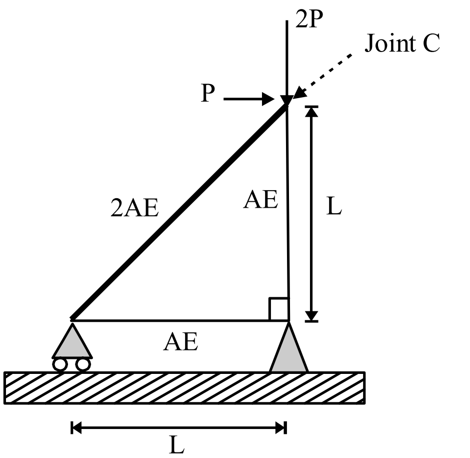
42. The dimensions of a symmetrical welded I-section are shown in the figure.



(All dimensions are in mm)

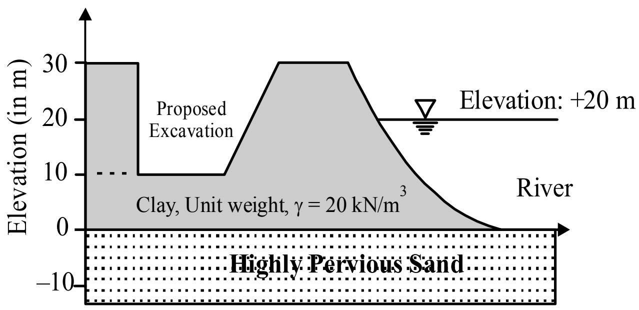
The plastic section modulus about the weaker axis (in cm^3, up to one decimal place) is ______

43. Consider the deformable pin-jointed truss with loading, geometry and section properties as shown in the figure.



Given that E = 2 × 10^{11} N/m^2, = 10 mm^2, L = 1 m and P = 1 kN. The horizontal displacement of Joint C (in mm, up to one decimal place) is ______

44. At a construction site, a contractor plans to make an excavation as shown in the figure.



The water level in the adjacent river is at an elevation of + 20.0 m. Unit weight of water is 10 kN/m^3. The factor of safety (up to two decimal places) against sand boiling for the proposed excavation is ______

45. A conventional drained triaxial compression test was conducted on a normally consolidated clay sample under an effective confining pressure of 200 kPa. The deviator stress at failure was found to be 400 kPa. An identical specimen of the same clay sample is isotropically consolidated to a confining pressure of 200 kPa and subjected to standard undrained triaxial compression test. If the deviator stress at failure is 150 kPa, the pore pressure developed (in kPa, up to one decimal place) is ______

46. The void ratio of a soil is 0.55 at an effective normal stress of 140 kPa. The compression index of the soil is 0.25. In order to reduce the void ratio to 0.4, an increase in the magnitude of effective normal stress (in kPa, up to one decimal place) should be ______

47. A rigid smooth retaining wall of height 7 m with vertical backface retains saturated clay as backfill. The saturated unit weight and undrained cohesion of the backfill are 17.2 kN/m^3 and 20 kPa, respectively. The difference in the active lateral forces on the wall (in kN per meter length of wall, up to two decimal places), before and after the occurrence of tension cracks is ______

48. Rainfall depth over a watershed is monitored through six number of well distributed rain gauges. Gauged data are given below

Rain Gauge Number	1	2	3	4	5	6
Rainfall Depth (mm)	470	465	435	525	480	510
Area of Thiessen Polygon ($\times 10^4$ m^2)	95	100	98	80	85	92

The Thiessen mean value (in mm, up to one decimal place) of the rainfall is ______

49. The infiltration rate f in a basin under ponding condition is given by $f = 30 + 10e^{-2t}$ where, f is in mm/h and t is time in hour. Total depth of infiltration (in mm, up to one decimal place) during the last 20 minutes of a storm of 30 minutes duration is ______

50. In a laboratory, a flow experiment is performed over a hydraulic structure. The measured values of discharge and velocity are 0.05 m^3/s and 0.25 m/s, respectively. If the full scale structure (30 times bigger) is subjected to a discharge of 270 m^3/s, then the time scale (model to full scale) value (up to two decimal places) is ______

51. A water sample analysis data is given below.

Ion	Concentration, mg/L	Atomic Weight
Ca^{2+}	60	40
Mg^{2+}	30	24.31
HCO_3^-	400	61

The carbonate hardness (expressed as mg/L of $CaCO_3$, up to one decimal place) for the water sample is ______

52. The ultimate BOD (L_0) of a wastewater sample is estimated as 87% of COD. The COD of this wastewater is 300 mg/L. Considering first order BOD reaction rate constant k (use natural log) = 0.23 per day and temperature coefficient θ = 1.047, the BOD value (in mg/L, up to one decimal place) after three days of incubation at 27°C for this wastewater will be ______

53. A waste activated sludge (WAS) is to be blended with green waste (GW). The carbon (C) and nitrogen (N) contents, per kg of WAS and GW, on dry basis are given in the table.

Parameter	WAS	GW
Carbon (g)	54	360
Nitrogen (g)	10	6

The ratio of WAS to GW required (up to two decimal places) to achieve a blended C:N ratio of 20:1 on dry basis is ______

54. Given the following data: design life n = 15 years, lane distribution factor D = 0.75, annual rate of growth of commercial vehicles r = 6%, vehicle damage factor F = 4 and initial traffic in the year of completion of construction = 3000 Commercial Vehicles Per Day (CVPD). As per IRC:37-2012, the design traffic in terms of cumulative number of standard axles (in million standard axles, up to two decimal places) is ______

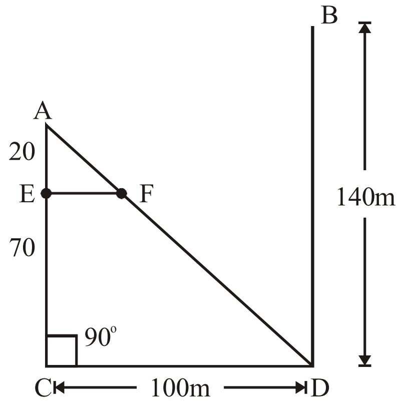
55. An aircraft approaches the threshold of a runway strip at a speed of 200 km/h. The pilot decelerates the aircraft at a rate of 1.697 m/s^2 and takes 18 s to exit the runway strip. If the deceleration after exiting the runway is 1 m/s^2, then the distance (in m, up to one decimal place) of the gate position from the location of exit on the runway is ______

HINTS & SOLUTIONS

General Aptitude Test

1. **(a)** brake, break
2. **(a)** Unpredictable
3. **(d)** Suppose, Hari's age is x years.
Let, Hema's age be H and Suresh's age be S.
Now. according to the question,
$H = 2x + 5, S = 10x - 13, S = 3H$
$\Rightarrow 10x - 13 = 3(2x + 5)$
$\Rightarrow x = 7$
So, H = 2 × 7 + 5 = 19 years

4. **(a)**



$AD = \sqrt{AC^2 + CD^2} = \sqrt{90^2 + 100^2}$
(By Pythagoras Theorem)
$AD = \sqrt{18100}$ m
Here, by applying Proportionality theorem for Δ AEF and Δ ACD

$\frac{AE}{AC} = \frac{EF}{CD}$

$\Rightarrow \frac{20}{90} = \frac{EF}{100}$

$\Rightarrow EF = \frac{200}{9} = 22.22m$

5. **(b)** $\therefore T = K(\theta p + To)$
According to the question
$32.4 = K(2\theta + 25)$
$42.0 = K(5\theta + 30)$

After dividing, we get: $\frac{32.4}{42.0} = \frac{20+25}{50+30}$

$\Rightarrow \frac{27}{35} = \frac{2\theta + 25}{5\theta + 30}$

$\Rightarrow \theta = 1^o$

6. **(c)** $\therefore 12.5\% = \frac{1}{8}$

and $10\% = \frac{1}{10}$

As, $\frac{SP}{CP} = 1 - \frac{1}{8} = \frac{7}{8}$ and $\frac{SP+108}{CP} = 1 + \frac{1}{10} = \frac{11}{10}$

$\Rightarrow \frac{108}{CP} = \frac{11}{10} - \frac{7}{8} = \frac{9}{40}$

$\Rightarrow CP = \frac{108 \times 40}{9} = 480$

Hence, loss (in Rs.) = CP × % Loss

$= 480 \times \frac{1}{8} =$ Rs. 60

7. **(b)** Since, Price α(Length)$^2 \Rightarrow$ Price $= kL^2$
According to the question,
$1600 = k(10)^2 \Rightarrow k = 16$

$\therefore$ New Price $= k\left[L_1^2 + L_2^2\right] = 16[4^2 + 6^2]$
$= 16 \times 52 =$ Rs.832

8. **(b)** By three parts of given graph.

9. **(c)** Since $a_n = \frac{1}{n} - \frac{1}{n+2}$
$\therefore a_1 + a_2 + a_3 + ... + a_{50}$

$\left[\left(1-\frac{1}{3}\right)+\left(\frac{1}{2}-\frac{1}{4}\right)+\left(\frac{1}{3}-\frac{1}{5}\right)+\left(\frac{1}{4}-\frac{1}{6}\right)+\right.$

$\left.+\left(\frac{1}{47}-\frac{1}{49}\right)+\left(\frac{1}{48}-\frac{1}{50}\right)+\left(\frac{1}{49}-\frac{1}{51}\right)+\left(\frac{1}{50}-\frac{1}{52}\right)\right]$

$= 1 + \frac{1}{2} - \frac{1}{51} - \frac{1}{52} = \left(1 + \frac{1}{2}\right) - \left(\frac{1}{51} + \frac{1}{52}\right)$

10. **(b)** According to question,

we get:

A (6)		D (8)
B (4)	G (2)	E (9)
C (3)		F (1)

Technical Section Test

1. **(c)** For a singular metrix.
Determenant of A = |A| = 0
So,
For, option |A| = 6 – 5 = 1
For, option |B| = 9 – 4 = 5
For, option |C| = 12 – 12 = 0

For, option $|D| = 8 - 18 = -10$
Hence, matrix C is singular Matrix.

2. (c) For orthogonal matrix (Q) , $Q^{-1}=, Q^T$

$$Q^T = \begin{bmatrix} \frac{3}{7} & \frac{-6}{7} & \frac{2}{7} \\ \frac{2}{7} & \frac{3}{7} & \frac{6}{7} \\ \frac{6}{7} & \frac{2}{7} & \frac{-3}{7} \end{bmatrix}$$

3. (d) $f(x) = x^3$
$f'(x) = 3x^2$
$3x^2 = 0$ at $x = 0$
$f''(x) = 6x$, at $x = 0$
$f''(x) \neq 0$;
Hence, at X=0, funution neither maximum nor minimum.

4. (a) $p_{u1} = \frac{\pi^2 E\, I_{1\ min}}{L^2 eff1}, [\therefore Leff_1 = h]$

$\therefore I_1 \min = \frac{2a \times a^3}{12} = \frac{a^4}{6}$

$p_{u1} = \frac{\pi^2 E \times a^4}{6h^2}$,

$p_{u2} = \frac{\pi^2 EI_{2\,min}}{L^2 eff_2}$, $[\therefore Leff_2 = 1.5h]$

$\left[\therefore I_2 \min = \frac{(0.5a)^3 \times 3a}{12}\right]$, $P_{u2} = \frac{\pi^2 Ea^4}{72h^2}$,

$pu_2 = \frac{pu_1}{12}$

5. (d) $F_u = 2000KN$ (self at neglected)
Area = a^2 (let a be a side)
Bering cepacity of concrete = 0.45 fck
$fc = 0.45 \times 20 = 9MPa$

$a^2 = \frac{fu}{fc} = \frac{2000 \times 10^3}{9 \times 10^6} = 2222222.2\,mm^2$

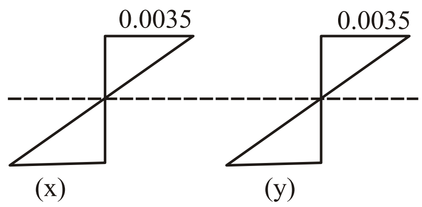
$a = 47.14cm \simeq 48cm$

6. (d) Le-chatelier's apporatus is used to determine the soundness of cement.

7. (a) deformation due to sustained loading is creep.

8. (a) $\frac{T}{J} = \frac{G\theta}{L} = \frac{q}{r}$, $q_{max} = \frac{T \times r}{J}$
here finishing moment is about Z-axis here, there is no shear stress in x-y plane. Hence, it is zero (OMPa)

9. (a) Mu = Tension × lever arm



here section X has less flexural strength and is less ductile than section Y.

10. (c) Ultimate bearning capacity
$q_u = CN_C + \gamma\ D_f Nq + 0.5$
$B\gamma\ N\gamma$ sand hence c = 0, water level at base, so $D_f = 0$
so $q_u = 0.5\,\gamma\, BN\gamma$
here $\gamma = \gamma$,when water table is at ground level ,

$\therefore\ \gamma' = \frac{\gamma}{2}$,

here $q_u = 0.25\,\gamma\, BN\gamma$

percentege reduction = $\frac{0.25\gamma BN\gamma}{0.5\gamma BN\gamma} \times 100\% = 50\%$

11. (c) q_u cirular = $1.3\, CN_C + \gamma\, D_f Nq + 0.3\ \gamma\ DN\gamma$
q_u square = $1.3CN_C + \gamma\, D_f Nq + 0.4\,\gamma\, DN\gamma$
here , soil is sandy, hence C = 0
footing are at surface of soil $D_f = 0$

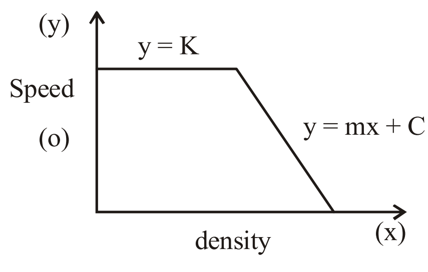
$\frac{q_u \text{ circular}}{q_u \text{ square}} = \frac{0.3}{0.4} = \frac{3}{4}$

12. (c) Bernoullis theorem is appllicable for ideal fluids (inviscid and incompressible fluids)

13. (a) Release by 20,000 vehicles
$= (12000 \times 2 \times 10^{-3} \times 20000) = 48,0000kg$

14. (b) 30 indicate range of viscosity = $[100 \pm 20] \times 30$
$= 3600$ or 2400

15. (c)



Flow = Speed * dencity
at y = K; Flow = kx
For linear ,
Y = mx + c
flow = (mx + c)x , = $mx^2 + cx$
Y = $mx^2 + cx$ (eqn of Parabola)

16. (b) The total delay must be minimized.

17. (1.5) $Wz = \frac{1}{2}\left[\frac{\delta v}{\delta x} - \frac{\delta u}{\delta y}\right]$

$$\frac{\delta v}{\delta x} = \frac{\delta(-xy)}{\delta x} - y$$

$$\frac{\delta u}{\delta y} = \frac{\delta(y^2)}{\delta y} = 2y$$

$$Wz = \frac{1}{2}[-y - 2y] = -3y/2$$

$$Wz \text{ at } (0, -1, 1) = \frac{-3 \times -1}{2} = 1.5$$

18. (15.487)

$$\mu = \frac{\sum nf}{\sum n}$$

$$= \frac{4 \times 23 + 2 \times 28 + 5 \times 22.5 + 5 \times 31 + 4 \times 29}{4 + 2 + 5 + 5 + 4}$$

$= 26.575$MPa

$$\sigma = \sqrt{\frac{\sum (f-\mu)^2 \cdot n}{n-1}}$$

$$= \sqrt{\frac{4 \times (23 - 26.575)^2 + (28 - 26.575)^2 \times 2 + 5 \times (31 - 26575)^2 + 5 \times (22.5 - 26.575)^2 + 4 \times (29 - 26.575)^2}{20 - 1}}$$

$= 3.697$

So, $\mu - 3\sigma = 26.575 - 3\,(3.697) = 15.487, 0$

Specimen have $f < 15.487$

19. (173.2)

$\tau = 50$MPa

$\sigma = 150$MPa

$$fe = \sqrt{\sigma^2 + 3\tau^2}$$

$$= \sqrt{150^2 + 3 \times 50^2}$$

$= 173.2$MPa

20. (19.9) Shrinkage limit = e/G

$G = 2.71, v = 50cm^3$; $M = 88g$

$$\gamma_d = \frac{M}{v} = \frac{88}{50} = 1.76$$

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

$$1 + e = \frac{G\gamma w}{\gamma_d} = \frac{2.71 \times 1}{1.76} \quad [\because \gamma_w = 1g/cm^3]$$

$$e = \frac{2.71}{1.76} - 1 = 0.539$$

$$S.L. = e/G = \frac{0.539}{2.71} = 0.199 = 19.9\%$$

21. (12.36)

$$Ar = \frac{D_o^2 - D_i^2}{D_i^2} \times 100\%$$

$$= \frac{106^2 - 100^2}{100^2} \times 100\% = 12.36\%$$

22. (0.06) $L_r = 50$

$Q_r = L_r^{2.5}$

here $Q_P = 1000m^3/sec$, $Qr = \frac{Q_P}{Q_M} = (50)^{2.5}$

$$Q_M = \frac{1000}{50^{2.5}} = 0.06$$

23. (1.11) $Q = 20m^3/s$, $q = \frac{20}{10} = 2m^3/s$

$Ec = 1.5y_e$

$$y_e = \left(\frac{q^2}{g}\right)^{\frac{1}{3}} = \left[\frac{4}{9.81}\right]^{\frac{1}{3}} = 0.7437$$

$Ec = 1.5 \times 0.7437, = 1.11m$

24. (0.7) According is muskingum method

$C_0 + C_1 + C_2 = 1$

$-0.25 + 0.55 + C_2 = 1, C_2 = 0.70$

25. (27272.7)

Waste generated per year = 40×10^6 kg ,

Waste that goes to landfill

$= 40 \times 10^6 - (10\% \text{ of } 40 \times 10^6) = 36 \times 10^6$ Kg.

Density (ρ) = $550kg/m^3$

Tatal volume of waste

$$V = = \frac{M}{\rho} = \frac{36 \times 10^6}{550} = 0.06545 \times 10^6 m^3 / \text{year}$$

$0.6545 \times 10^6 = 80\%$ of valume

$$\text{total volume of lendfill} = \frac{0.6545 \times 10^6}{0.8}$$

$= 81818.8m^3$/year , [$\therefore$ hight = 3m]

$$\Rightarrow \text{Area} = \left[\frac{81818.8}{3}\right] = 27272.7m^2$$

26. (b) $\int_0^{\pi} x\cos^2 x\,dx$, $\cos^2 x = \frac{1+\cos 2x}{2}$

$$\int_0^{\pi} x\left[\frac{1+\cos 2x}{2}\right]dx = \int_0^{\pi}\left(\frac{x}{2}+\frac{x\cos 2x}{2}\right)dx$$

$$= \frac{1}{2}\times\left[\frac{x^2}{2}+x\times\frac{\sin 2x}{2}+\frac{1}{4}\cos 2x\right]_0^{\pi}$$

$$= \frac{1}{2}\left[\frac{\pi^2}{2}+\frac{1}{4}+0-0+0-\frac{1}{4}\right],\ = \frac{\pi^2}{4}$$

27. (b) $\delta_{max} = \frac{PL^3}{3EI}$

$$\Rightarrow 5\times10^{-3} = \frac{p\times2^3}{3\times2\times10^{11}\times I}$$

$$\left[\therefore I = \frac{0.1\times0.1^3}{12} = 8.33\times10^{-6}\right]$$

$$\text{So, } p = \frac{5\times10^{-3}\times3\times2\times10^{11}\times8.33\times10^{-6}}{2^3}$$

$= 31.24\times10^2$N

σ (Maximum bending stress) at free end =

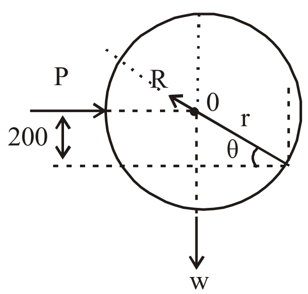
$$\left[\because M = 2P,\ b = d = 0.1\ M\right]$$

$$\frac{M}{Z} = \frac{6M}{bd^2}$$

$$= \frac{6\times2\times p}{0.1\times0.1^2}$$

= 37.5Mpa

28. (d) FBD of cylinder



$$\sin\theta = \frac{200}{r} = \frac{200}{250}$$

$\theta = 53.13°$

$\sum Fy = 0$

w = R sin 53.13

10 = R sin 53.13

R = 10 / sin 53.13

$\sum F_x = 0$,

P = R cos 53.13

$$P = \frac{10\cos 53.13}{\sin 53.13}$$

P = 7.5KN

29. (a) $E\,\varepsilon_z = \sigma_z - \mu\times\sigma_x - \mu\times\sigma_y$

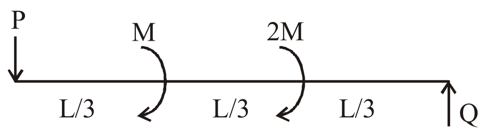
$$\left[\begin{array}{l}\therefore\ \sigma x=30,\ \sigma y=50\\ \quad \sigma z=0,\ \mu=0.3\\ \therefore E = 2\times10^{11}\,N/mm^2\end{array}\right]$$

$$\varepsilon_z = \frac{(0-0.3\times30-0.3\times50)}{2\times10^{11}}$$

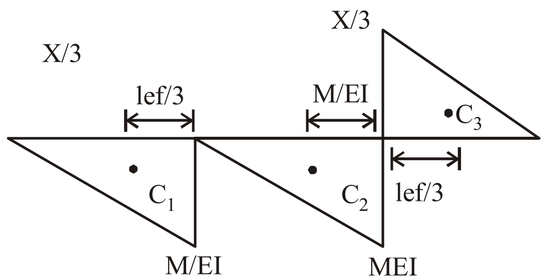
$$= \frac{-12\times10^6}{10^{11}} = -12\times10^{-5}$$

$= -120\times10^{-6}$

30. (c)



$$P = \frac{M}{\ell/3} \qquad Q = \frac{M}{\ell/3}$$



$$p\times l-\frac{Ml}{6El}\times\left[\frac{2l}{3}+\frac{l}{\frac{3}{3}}\right]=\frac{Ml}{6El}\left[\frac{l}{3}+\frac{l}{3\times 3}\right]$$

$$+\frac{M1}{6EI}\left[\frac{l}{3}-\frac{l}{3\times 3}\right]=0$$

$$Pl=\frac{M\times l}{18\,EI}\left[2l+\frac{l}{3}+l+\frac{l}{3}-l+\frac{l}{3}\right]$$

$$p=\frac{M}{18EI}\times 3l=\frac{Ml}{6EI}$$

31. (c)

$Q_u = C\,NcAp + \alpha\, C_u PL$.....(i)

$Q_u = Fos\times Q = 2\times 500 = 1000KN$

$C = 50, Nc = 9$ (given)

$Ap = 0.5\times 0.5, \alpha = 0.75$

From (i)

$i, e: 1000 = 50\times 9\times 0.5^2 + (0.75\times 50\times 4\times 0.5L)$

$L = 11.83m, = 11.8m$

32. (a) $P_{bottom} = Pg + 0.6\times 3\times 9.81 + 1\times 2\times 9.81 + 13.6\times 0.5\times 9.81$

$196.2 = 103.98.6 + pg,$

$pg = 92.214KN/m^2$

33. (c) Total volume of water for filtering

$= 99MLD + \frac{5}{100}\times 99 = 99 + 4.95$

$= 103.95\ MLD$

$r = 6m/h$

volume of water filtering in per hr.

$= 6\times$ area of filtering $= 6\times L\times B$

$L = 1.35\times 5.2 = 7.02m$

$V = 6\times 7.02\times 5.2 = 219.0244m^3$

volume of water filtered in 1 day

$= 24\times 219.0244 = 5256.58m^3 = 5.256\ MLD$

No. of filter required $= \frac{V}{V\text{ in 1day}}$

$= \frac{103.95}{5.256} = 19.77 \approx 20$

but 1 filter is required in case of break down/repair

Hence, total no of beds = 20 + 1 = 21

34. (b) SSD (single lane)

$$= Vt + \frac{V^2}{2gf}, \left[\begin{array}{l}\because V = 20kmgh\\ = 2\times\frac{5}{18} = 5.56M/S\end{array}\right]$$

$$= 5.56\times 2.5 + \frac{5.56^2}{2\times 9.81\times 0.38}$$

$= 18.05M = 18m$,

SSD_2 on 2 lane road

$$= v_1 t + \frac{v_1^2}{2gf}, \left[\begin{array}{l}\because 50kmgh\\ = 50\times\frac{5}{18} = 13.89m/s\end{array}\right]$$

$$= 13.89\times 2.5 + \frac{13.89^2}{2\times 9.81\times 0.38}$$

$= 60.59m, = 61m$

35. (a) $\sum L = \sum N - \sum S = (101+419) - (437+83) = 0,$

$\sum D = \sum E - \sum W = (173+588) - (96+634) = 1,$

$L = \sqrt{\sum L^2 + \sum D^2} = 1m,$

$\tan\theta = \frac{\sum D}{\sum L} = \frac{1}{0} = \infty$

$\theta = 90°$ or $270°$

36. (c) $S = \frac{f}{H-h} = \frac{1}{10000},$

$\Rightarrow \frac{1}{10000} = \frac{150\times 10^{-3}}{H-650}$

$H - 650 = 150\times 10^4\times 10^{-3}$

$H = 1500 + 650, = 2150m$

37. (d) $\frac{d^2u}{dx^2} = 25\frac{d^2u}{dt^2},$

$$\frac{d^2u}{dt^2} = \frac{1}{25}\frac{d^2u}{dx^2} = \frac{d^2u}{dt^2} = C^2\times\frac{d^2u}{dx^2}$$

here $C^2 = \frac{1}{25}, C = \frac{1}{5}, f(x) = 3x\,; g(y) = 3$

by D'alemberts Wave eqn solution

$$u(x,t) = \frac{1}{2}\left[f(x+ct) + f(x-ct)\right] + \frac{1}{2c}\int_{x-ct}^{x+ct} g(y)dy$$

$$= \frac{1}{2}\left[3\times\left[x+\frac{1}{5}t\right] + 3\left[x-\frac{1}{5}t\right] + \frac{5}{2}\int_{x-\frac{1}{5}t}^{x+\frac{1}{5}t} 3dy\right]$$

$$= \frac{1}{2}\left[3\times\left[x+\frac{1}{5}t+x-\frac{1}{5}t\right]+\frac{15}{2}\left[x+\frac{1}{5}t-x+\frac{1}{5}t\right]\right]$$

$= 3x + 3t$

$u(1,1) = 3+3 = 6$

38. (0.378)

$$\frac{d^2y}{dx^2}+\frac{2dy}{dx}+y=0$$

$(D^2+2D+1)y=0$, $(D+1)^2y=0$

auxillary equ is $(m+1)^2y=0$

$m+1=0, m+1=0, m=-1, -1$

$CF = y_1 = e^{-x}[C_1+C_2x]$

$PI = y_2 = 0,$

$CF + PI = e^{-x}[c_1+c_2x]$ at $y(0)=1$

$C_1 = 1,$

$$\frac{dy}{dx} = e^{-x}\left[0+C_2\right]+\left[C_1+C_2x\right]\times e^{-x}\times -1$$

$$= C_2e^{-x}-C_1e^{-x}-C_2xe^{-x}$$

at $x=0$, $\frac{dy}{dx}=-1$, $c_2=0$

so $y = e^{-x}[1+0] = e^{-x}$

at $x=1$ $y(1)=e^{-1}, = 0.3678$

39. (0.793)

$$\frac{dy}{dx}=\frac{1-e^{\frac{-10}{3}\ln y}}{250-45e^{-3\ln y}}$$

According to Euler's

$y_1 = y_0 + f'(x_0, y_0)\ \Delta x$

$(\therefore y_0 = 0.8m,\ \Delta x = 1, x_0 = 0)$

$$Y_1 = 0.8+\frac{1-e^{\frac{-10}{3}\ln 0.8}}{250-45e^{-3\ln 0.8}}\times 1$$

$= 0.7931m$

40. (918.084)

$P_u = 0.45\ f_{ck}\ Ac + 0.75\ fy\ Asc$

$$= 0.45\times 20\times 250\times 300+0.75\times 415\times\left[\frac{4\times\pi}{4}\times 16^2\right]$$

$= 918084\ N = 918.084\ kN$

41. (8.2) $\tau_v = V_u/bd$

$$= \frac{200\times 10^3}{250\times 350} = 2.286\ MPa$$

$\tau_{C_{max}} = 2.8\ MPa$

$\tau_{C_{max}} > \tau_v$, hence safe

Design shear force $= (\tau_v - \tau_c)$ bd

$= (2.286-0.62)\times 250\times 350 = 145775\ N$

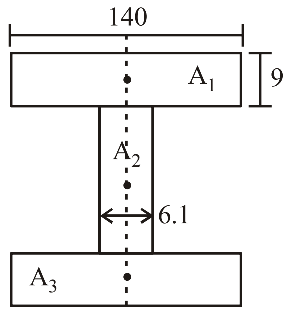
$$\frac{V_{us}}{0.87f_y\ A_{st}} = \frac{b}{S_v}$$

$$Sv = \frac{0.87fy\ A_{st}\times b}{V_{us}}$$

$$= \frac{0.87\times 250\times\frac{\pi}{4}\times 10^2\times 2\times 350}{145775}$$

$= 82.03\ mm \simeq 8.203\ cm$

42. (89.9)



$A = A_1 + A_2 + A_3$

$= 140\times 9 + 6.1\times 182 + 140\times 9 = 3630.2\ mm^2$

$$\bar{y}_1 = \frac{A_1y_1+A_2y_2+A_3y_3}{A_1+A_2+A_3}$$

$$= \frac{\frac{140}{2}\times 9\times\frac{70}{2}+182\times\frac{6.1}{2}\times\frac{6.1}{4}+\frac{140}{2}\times 9\times\frac{70}{2}}{70\times 9+182\times\frac{6.1}{2}+70\times 9}$$

$= 24.763\ mm$

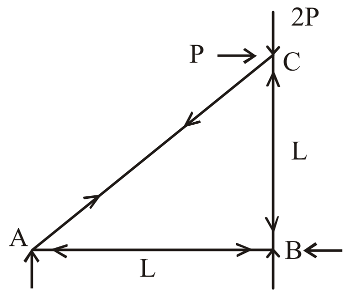
$\bar{y}_1 = \bar{y}_2$, (Symmetrical)

hence, $z_p = \frac{A}{2}\left[y_1+y_2\right]$

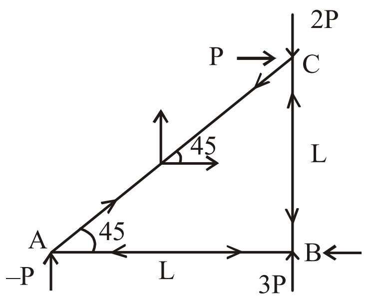
$$= \frac{3630.3}{2}\left[24.763+24.763\right] = 89894.64\ mm^3$$

$= 89.9\ cm^3$

43. (2.7)



$\Sigma F_y = 0$
$R_A + R_B = 2P$
$\Sigma F_x = 0$
$R_{B_H} = P$
$\Sigma M_A = 0$
$2P \times L - R_B \times L + P \times L = 0$
$3PL = R_B \times L$
$R_B = 3P$
So $R_A = -P$
To find member forces



Joint A:
$\Sigma F_y = 0$
$-P + R_{AC} \sin 45 = 0$
$R_{AC} = P/0.707$
$\Sigma F_x = 0$
$R_{AB} = -P$
Joint C:
$\Sigma F_y = 0$
$-(2P + P) = R_{BC}$
$-3P = R_{BC}$
Remove all loads and apply an external load kN at C.

Now $R'_{AC} = \sqrt{2}$

$R'_{BC} = -1$

$R'_{AB} = -1$

Horizontal displacement at

$$C = \frac{3PL}{AE} + \frac{2\sqrt{2}PL}{2AE} + \frac{PL}{AE}$$

$$= \frac{5.414PL}{AE}$$

$$= \frac{5.414 \times 1 \times 10^3 \times 10^3}{10 \times 10 \times 2 \times 10^5}$$

= 2.7 mm

44. (1) Uplift due to Pore water pressure = $\gamma \omega \times t$
$= 20 \times 10 = 200\ \text{kN/m}^3$

(2) Downward pressure at send-clay interface
$= 10 \times \gamma$
$= 10 \times 20 = 200\ \text{kN/m}^3$

$$\text{Fos} = \frac{200}{200} = 10$$

45. (125) $\sigma_3 = 200$ kPa
$\sigma_d = 400$ kPa
$\sigma_1 = \sigma_d + \sigma_3$
$= 400 + 200 = 600$ kPa

$$\sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi'}{2}\right) + 2\tan\left(45 + \frac{\phi'}{2}\right)$$

$$600 = 200 \tan^2\left(45 + \frac{\phi'}{2}\right)$$

$$3 = \tan^2\left(45 + \frac{\phi'}{2}\right)$$

$$\sqrt{3} = \tan\left(45 + \frac{\phi'}{2}\right)$$

$$45 + \frac{\phi}{2} = 60,\ \phi = 30°$$

for cu test

$$\sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi'}{2}\right) + 2c\tan\left(45 + \frac{\phi'}{2}\right)$$

$\sigma_c + \Delta\sigma_a - u = [\sigma_c - u] \tan^2 60$

$(200 + 150 - u) = [200 - 4] \times \left(\sqrt{3}\right)^2$

$(350 - u) = (600 - 3u)$
$2u = 250$
$u = 125$ kPa

46. (417.35)

$$C_C = \frac{\Delta e}{\log (p_2 / p_1)}$$

$$0.25 = \frac{0.55 - 0.4}{\log\left[p_2/140\right]}$$

$$\log\left[P_2/140\right] = 0.6$$

$\log P_2 - \log 140 = 0.6$
$P_2 = 10^{2.74}$
$= 557.35$ kN
$\Delta\sigma = \sigma_2 - \sigma_1$
$= 557.35 - 140$
$= 417.35$ kPa