ESE 2026

PRELIMINARY EXAMINATION

CIVIL ENGINEERING

[Volume-I]

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ESE 2026 [Preliminary Examination]

Civil Engineering

Volume-I

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Exam Pattern

A. Stage-I (Preliminary/Stage-I) Examination :

Subject	Duration	Maximum Marks
Category - I Civil Engineering		
Paper-I (General Studies and Engineering Aptitude)	2 hrs.	200
Paper-II (Civil Engineering)	3 hrs.	300
Total		500

B. Stage-II (Main/Stage-II) Examination :

Subject	Duration	Maximum Marks
Category - I Civil Engineering		
Paper-I (Civil Engineering)	3 hrs.	300
Paper-II (Civil Engineering)	3 hrs.	300
Total		600

Syllabus

Paper-I Syllabus :

Contents for syllabi of both the Papers together for Preliminary Examination/Stage-I (objective type Paper–II) and separately for Main/Stage-II Examination (Conventional type Paper-I and Paper – II).

1. **Building Materials :** Stone, Lime, Glass, Plastics, Steel, FRP, Ceramics, Aluminum, Fly Ash, Basic Admixtures, Timber, Bricks and Aggregates: Classification, properties and selection criteria;
   Cement : Types, Composition, Properties, Uses, Specifications and various Tests; Lime & Cement Mortars and Concrete: Properties and various Tests; Design of Concrete Mixes: Proportioning of aggregates and methods of mix design.
2. **Solid Mechanics :** Elastic constants, Stress, plane stress, Strains, plane strain, Mohr's circle of stress and strain, Elastic theories of failure, Principal Stresses, Bending, Shear and Torsion.
3. **Structural Analysis :** Basics of strength of materials, Types of stresses and strains, Bending moments and shear force, concept of bending and shear stresses; Analysis of determinate and indeterminate structures; Trusses, beams, plane frames; Rolling loads, Influence Lines, Unit load method & other methods; Free and Forced vibrations of single degree and multi degree freedom system; Suspended Cables; Concepts and use of Computer Aided Design.
4. **Design of Steel Structures :** Principles of Working Stress methods, Design of tension and compression members, Design of beams and beam column connections, built-up sections, Girders, Industrial roofs, Principles of Ultimate load design.
5. **Design of Concrete and Masonry Structures :** Limit state design for bending, shear, axial compression and combined forces; Design of beams, Slabs, Lintels, Foundations, Retaining walls, Tanks, Staircases; Principles of pre-stressed concrete design including materials and methods; Earthquake resistant design of structures; Design of Masonry Structure.
6. **Construction Practice, Planning and Management :** Construction - Planning, Equipment, Site investigation and Management including Estimation with latest project management tools and network analysis for different Types of works; Analysis of Rates of various types of works; Tendering Process and Contract Management, Quality Control, Productivity, Operation Cost; Land acquisition; Labour safety and welfare.

Paper-II Syllabus :

1. **Flow of Fluids, Hydraulic Machines and Hydro Power :**
   (a) **Fluid Mechanics, Open Channel Flow, Pipe Flow :** Fluid properties; Dimensional Analysis and Modeling; Fluid dynamics including flow kinematics and measurements; Flow net; Viscosity, Boundary layer and control, Drag, Lift, Principles in open channel flow, Flow controls. Hydraulic jump; Surges; Pipe networks.
   (b) **Hydraulic Machines and Hydro power :** Various pumps, Air vessels, Hydraulic turbines – types, classifications & performance parameters; Power house –classification and layout, storage, pondage, control of supply.

2. **Hydrology and Water Resources Engineering :** Hydrological cycle, Ground water hydrology, Well hydrology and related data analysis; Streams and their gauging; River morphology; Flood, drought and their management; Capacity of Reservoirs.

   Water Resources Engineering : Multipurpose uses of Water, River basins and their potential; Irrigation systems, water demand assessment; Resources - storages and their yields; Water logging, canal and drainage design, Gravity dams, falls, weirs, Energy dissipaters, barrage Distribution works, Cross drainage works and head-works and their design; Concepts in canal design, construction & maintenance; River training, measurement and analysis of rainfall.

3. **Environmental Engineering :**

   (a) Water Supply Engineering : Sources, Estimation, quality standards and testing of water and their treatment; Rural, Institutional and industrial water supply; Physical, chemical and biological characteristics and sources of water, Pollutants in water and its effects, Estimation of water demand; Drinking water Standards, Water Treatment Plants, Water distribution networks.

   (b) Waste Water Engineering : Planning & design of domestic waste water, sewage collection and disposal; Plumbing Systems. Components and layout of sewerage system; Planning & design of Domestic Waste-water disposal system; Sludge management including treatment, disposal and re-use of treated effluents; Industrial waste waters and Effluent Treatment Plants including institutional and industrial sewage management.

   (c) Solid Waste Management : Sources & classification of solid wastes along with planning & design of its management system; Disposal system, Beneficial aspects of wastes and Utilization by Civil Engineers.

   (d) Air, Noise pollution and Ecology : Concepts & general methodology.

4. **Geo-technical Engineering and Foundation Engineering :**

   (a) Geo-technical Engineering : Soil exploration - planning & methods, Properties of soil, classification, various tests and interrelationships; Permeability & Seepage, Compressibility, consolidation and Shearing resistance, Earth pressure theories and stress distribution in soil; Properties and uses of geo-synthetics.

   (b) Foundation Engineering : Types of foundations & selection criteria, bearing capacity, settlement analysis, design and testing of shallow & deep foundations; Slope stability analysis, Earthen embankments, Dams and Earth retaining structures: types, analysis and design, Principles of ground modifications.

5. **Surveying and Geology :**

   (a) Surveying : Classification of surveys, various methodologies, instruments & analysis of measurement of distances, elevation and directions; Field astronomy, Global Positioning System; Map preparation; Photogrammetry; Remote sensing concepts; Survey Layout for culverts, canals, bridges, road/railway alignment and buildings, Setting out of Curves.

   (b) Geology : Basic knowledge of Engineering geology & its application in projects.

6. Transportation Engineering :

Highways : Planning & construction methodology, Alignment and geometric design; Traffic Surveys and Controls; Principles of Flexible and Rigid pavements design.

Tunneling : Alignment, methods of construction, disposal of muck, drainage, lighting and ventilation.

Railways Systems : Terminology, Planning, designs and maintenance practices; track modernization.

Harbours : Terminology, layouts and planning.

Airports : Layout, planning & design.

CONTENT

1 STRENGTH OF MATERIALS

Syllabus : Strength of Materials

Elastic constants, Stress, plane stress, Strains, plane strain, Mohr's circle of stress and strain, Elastic theories of failure, Principal Stresses, Bending, Shear and Torsion.

Contents : Strength of Materials

1 Strength of Materials

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1.1 Given that for an element in a body of homogeneous isotropic material subjected to plane stress; $\varepsilon_x, \varepsilon_y$ and ε_z are normal strains in *x*, *y*, *z* directions respectively and μ is the Poisson's ratio, the magnitude of unit volume change of the element is given by

(A) $\varepsilon_x + \varepsilon_y + \varepsilon_z$ (B) $\varepsilon_x - \mu(\varepsilon_y + \varepsilon_z)$ (C) $\mu(\varepsilon_x + \varepsilon_y + \varepsilon_z)$ (D) $\frac{1}{\varepsilon_x} + \frac{1}{\varepsilon_y} + \frac{1}{\varepsilon_z}$

Sol. **(A)**

Unit volume change, $\frac{\Delta V}{V} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}} \sqrt{a^2 + b^2}$

$$\frac{\Delta V}{V} = \frac{(1+\varepsilon_x)(1+\varepsilon_y)(1+\varepsilon_z) - 1}{1}$$

$$\frac{\Delta V}{V} = 1 + \varepsilon_x + \varepsilon_y + \varepsilon_z + \varepsilon_x\varepsilon_y + \varepsilon_y\varepsilon_z + \varepsilon_z\varepsilon_x + \varepsilon_x\varepsilon_y\varepsilon_z - 1$$

Product of strain terms are very small, so neglecting them hence

$$\frac{\Delta V}{V} = \varepsilon_x + \varepsilon_y + \varepsilon_z$$

Hence, the correct option is (A).

1.2 A solid metal bar of uniform diameter *D* and length *L* is hung vertically from a ceiling. If the density of the material of the bar is ρ and the modulus of elasticity is E, then the total elongation of the bar due to its own weight is

(A) $\frac{\rho L}{2E}$ (B) $\frac{\rho L^2}{2E}$ (C) $\frac{\rho E}{2L}$ (D) $\frac{\rho E}{2L^2}$

Sol. **(B)**

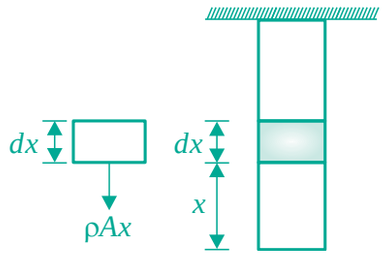
Elongation in length, dx is $d\delta$,

$$d\delta = \frac{P dx}{AE}$$

For a force of *P* on element (dx)

$$\int d\delta = \int_0^L \frac{Ax\rho dx}{AE}$$

$$\delta = \int_0^L \frac{\rho}{E}\frac{x^2}{2} = \frac{\rho L^2}{2E} = \rho\int_0^L \frac{x^2}{2E} = \frac{\rho L^2}{2E}$$



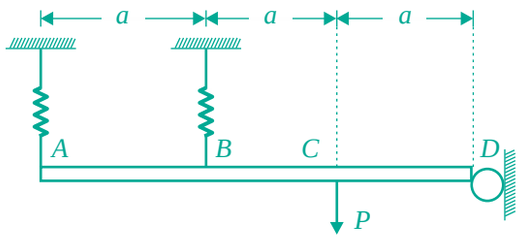
Hence, the correct option is (B).

Alternative :

The elongation of bar due to its own weight (w) is, $\Delta = \frac{WL}{2AE} = \frac{\rho AL \cdot L}{2AE} = \frac{\rho L^2}{2E}$

Hence, the correct option is (B).

1.3 A rigid beam $ABCD$ is hinged at D and supported by two springs at A and B as shown in the given figure. The beam carries a vertical load P at C The stiffness of spring at A is 2 K and that of B is K.



The ratio of forces of spring at A and that of spring at B is

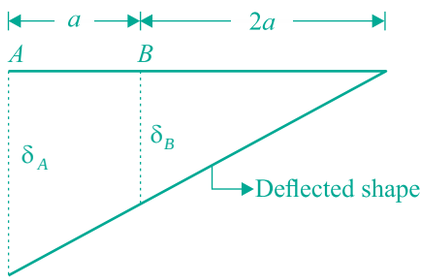
(A) 1 (B) 2 (C) 3 (D) 4

Sol. **(C)**

Given : $K_A = 2K_B$

Force carried by spring at A $= F_A = k_A\delta_A \Rightarrow 2k_B\delta_A$

Force carried by spring at B $= F_B = k_B\delta_B$

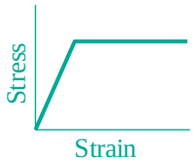


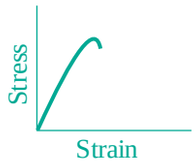
From similar triangles, $\frac{\delta_A}{3a} = \frac{\delta_B}{2a} \Rightarrow \delta_A = 1.5\delta_B$

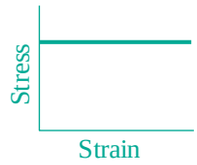
$$\frac{F_A}{F_B} = \frac{2k_B\delta_A}{k_B\delta_B} = \frac{2\delta_A}{\delta_B} = \frac{2\times 1.5\delta_B}{\delta_B} = 3$$

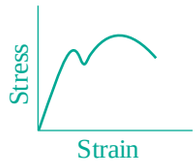
Hence, the correct option is (C).

1.4 The stress-strain curve for an ideally plastic material is

(A) 

(B) 

(C) 

(D) 

Sol. **(C)**

An ideal plastic material experiences no elastic deformation.

Hence, the correct option is (C).

1.5 A steel cube of volume 8000 cc is subjected to an all round stress of 1330 kg/sq. cm. The bulk modulus of the material is 1.33×10^6 kg/sq. cm. The volumetric change is

(A) 8 cc (B) 6 cc (C) 0.8 cc (D) 10^{-3} cc

Sol. **(A)**

Bulk modulus $= \frac{-P}{\frac{\Delta V}{V}}$

$$1.33\times10^6 = \frac{1330}{\frac{\Delta V}{8000}}$$

$$\Delta V = -8\,\text{cc}$$

(–) ve sign indicates reduction in volume if stress is compressive in nature.

Hence, the correct option is (A).

1.6 In terms of bulk modulus (K) and modulus of rigidity (G), the Poisson's ratio can be expressed as

(A) $\frac{(3K-4G)}{(6K+4G)}$ (B) $\frac{(3K+4G)}{(6K-4G)}$ (C) $\frac{(3K-2G)}{(6K+2G)}$ (D) $\frac{(3K+2G)}{(6K-4G)}$

Sol. **(C)**

We know, $E = 2G(1+\mu)$ …(i)

$E = 3K(1-2\mu)$ …(ii)

(where μ is Poisson's ratio)

Equation (i) ÷ (ii), $1 = \frac{2}{3}\frac{G}{K}\frac{(1+\mu)}{(1-2\mu)}$

$$3K - 6K\mu = 2G + 2G\mu$$

$$\mu = \frac{3K - 2G}{6K + 2G}$$

Hence, the correct option is (C).

1.7 Two bars one of material A and the other of material B of same length are tightly secured between two unyielding walls. Coefficient of thermal expansion of bar A is more than that of B. When temperature rises the stresses induced are

(A) Tension in both materials

(B) Tension in material A and compression in material B

(C) Compression in material A and tension in material B

(D) Compression in both materials

Sol. **(D)**

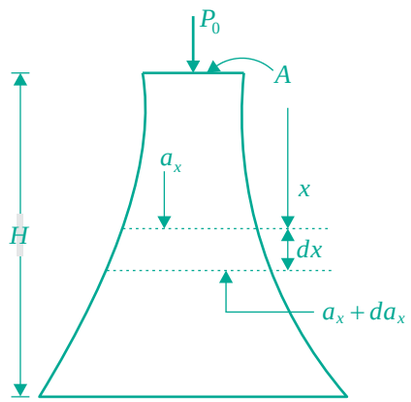
As the temperature rises, both the bars will have tendency to expand but they are fixed between two unyielding walls so they will not be allowed to expand. Hence in both the bars compressive stress will develop.

Hence, the correct option is (D).

1.8 A column of height 'H' and area at top 'A' has the same strength throughout its length, under its own weight and applied stress 'P_0' at the top. Density of column material is 'ρ'. To satisfy the above condition, the area of the column at the bottom should be.

(A) $Ae^{\left(\frac{HP_0}{\rho g}\right)}$ (B) $Ae^{\left(\frac{-\rho gH}{P_0}\right)}$ (C) $Ae^{\left(\frac{\rho gH}{P_0}\right)}$ (D) $Ae^{\left(\frac{H}{\rho gP_0}\right)}$

Sol. **(C)**



As we move down weight of column will add up to produce stresses. Since the column has same strength, so to satisfy the condition, the X-sectional area must increase as we move down.

Let area at distance x be a_x and in length dx.

Weight, added $= \rho g a_x dx$

2 Shear Force & Bending Moment

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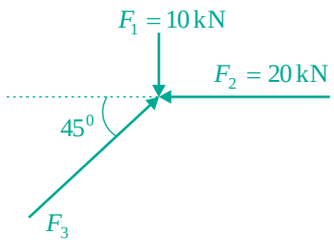
2.1 For the coplanar concurrent system of forces as shown in the given figure, the system will be



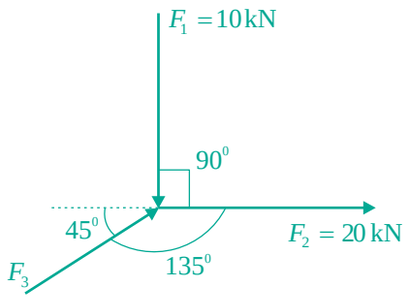
(A) In equilibrium if $|F_3| = 10\,\text{kN}$

(B) In equilibrium if $|F_3| = 10\sqrt{2}\,\text{kN}$

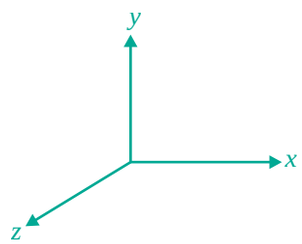
(C) In equilibrium if $|F_3| = 20\,\text{kN}$

(D) Will not be in equilibrium whatever be the magnitude of F_3

Sol. **(D)**



For equilibrium : $\sum F_x = 0$, $\sum F_y = 0$ and $\sum M_z = 0$



All forces are passing through one point $\sum M = 0$ satisfied.

But from force equilibrium, $F_3 \sin 45^0 - F_1 = 0$

$$F_3 \cos 45^0 - F_2 = 0$$

$$\frac{F_1}{F_2} = \tan 45^0 = 1$$

Which is not possible as given $F_1 \neq F_2$ for any value of F_3.

Hence, the correct option is (D).

Alternative :

From sine rule, $$\frac{F_1}{\sin 135} = \frac{F_2}{\sin 135^0} = \frac{F_3}{\sin 90^0}$$

$F_1 = F_2$ but $F_1 \neq F_2$

So for different value of F_1 and F_2 system will not be in equilibrium.

Hence, the correct option is (D).

2.2 **Assertion (A) :** Bending moment in a beam is maximum at a section where shear force is zero

Reason (R) : Shear force at a section is given by the rate of change of bending moment.

(A) Both A and R are true and R is correct explanation of A

(B) Both A and R are true but R is not a correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

Sol. **(A)**

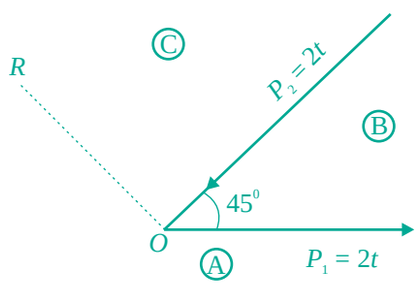
For bending moment M to be maximum, $\frac{dM}{dx} = 0$

We know, $$\frac{dM}{dx} = V$$

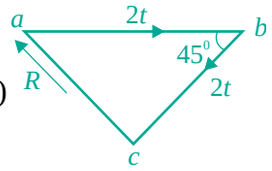
Thus, shear force at a section is given by the rate of change of bending moment and value of bending moment is maximum at the section where shear force is zero or changes sign.

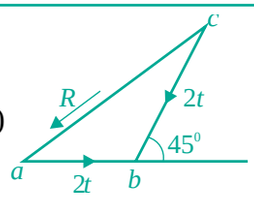
Hence, the correct option is (A).

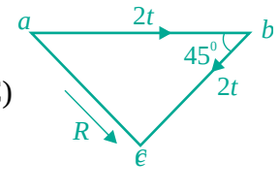
2.3 Two coplanar concurrent forces $P_1 = 2t$ and $P_2 = 2t$ meeting at O act on a lamina at 45° as shown in figure.

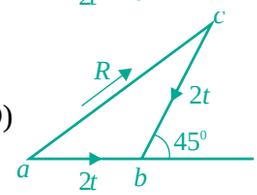


From the force diagram the force R to be applied at O in order to keep the body in equilibrium is given by

(A)


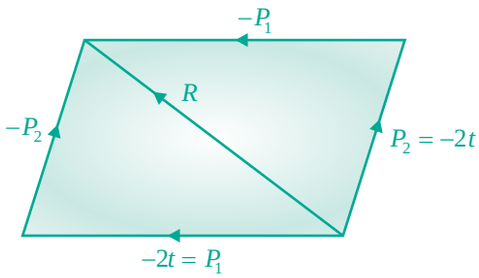
(B)


(C)


(D)


Sol. **(A)**

Using parallelogram law of forces



The resultant of P_1 and P_2 will form close triangle with given directions but to keep it in equilibrium the R should be applied opposite to resultant of P_1 and P_2.

Hence, the correct option is (A).

2.4 Parallelogram law of forces states that if two forces acting simultaneously at a point be represented in magnitude and direction by two adjacent sides of a parallelogram, their resultant may be represented in magnitude and direction by

(A) Longer side of the other two sides

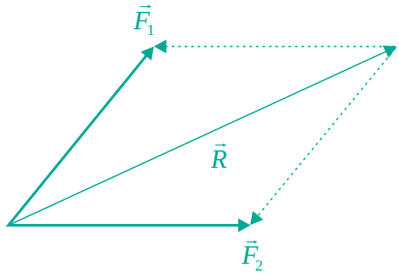
(B) Shorter side of the other two sides

(C) Diagonal of the parallelogram which does not pass through their point of intersection

(D) Diagonal for the parallelogram which passes through their point of intersection

Sol. **(D)**

Parallelogram Law of Forces :



R is the resultant of forces $\vec{F}_1$ and $\vec{F}_1$

Hence, the correct option is (D).

Note : Equivalent bending moment is that bending moment which while acting alone produces maximum normal stress equal to that produced due to combined action of bending and torsion.

2.5 Match **List-I (Type and position of load on cantilever)** with **List-II (Shape of bending moment diagram for cantilever)** and select the correct answer using the codes given below the lists :

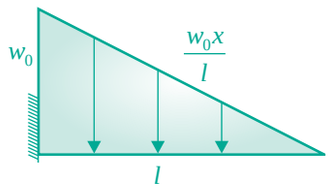
List-I		List-II	
A.	Carrying linearly varying load from zero at its free end and maximum at the fixed end	**1.**	Parabola
B.	Subjected to uniformly distributed load	**2.**	Rectangle
C.	Carrying concentrated load at its free end	**3.**	Cubic parabola
D.	Free end is subjected to bending moment	**4.**	Triangle

Codes :

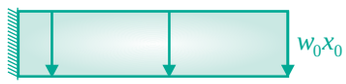
	A	**B**	**C**	**D**
(A)	3	2	1	4
(B)	4	3	2	1
(C)	3	1	4	2
(D)	2	4	1	3

Sol. **(C)**

If loading is of nth degree, then shear force diagram is of $(n + 1)$ degree and bending moment diagram is of $(n + 2)$ degree.

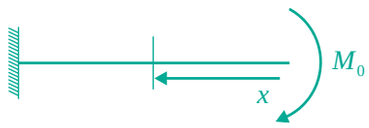


$n = 1$, BMD is 3rd degree.



$n = 0$, BMD is a 2nd degree.

$M = -Px$, BMD is a triangle.



$M = -M_0$, BMD is rectangular.

Hence, the correct option is (C).

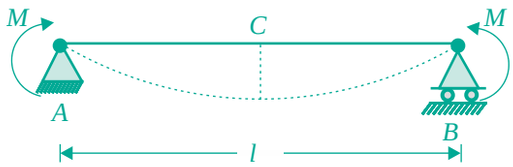
3 Deflection of Beams

ESE 1995

3.1 A beam simply-supported at both the ends, of length 'l' carries two equal unlike couples M at two ends. If the flexural rigidity El = constant, then the central deflection of beam is given by

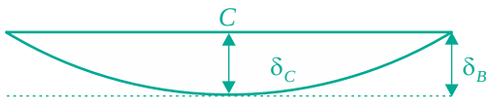
(A) $Ml^2/4EI$ (B) $Ml^2/16EI$ (C) $Ml^2/64EI$ (D) $Ml^2/8EI$

Sol. **(D)**



Using Moment Area Method,

At the centre, θ will be zero,



$$\theta_c = 0$$

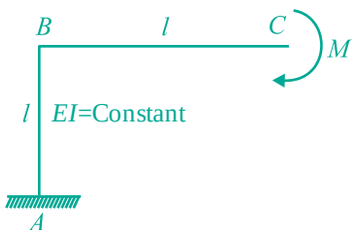
$$\delta_c = \delta_B$$

$\delta_c =$ Moment of area of $\frac{M}{EI}$ diagram between C and B about B $= \frac{l}{2} \times \frac{M}{EI} \times \frac{l}{4}$.

$$\delta_c = \frac{Ml^2}{8EI}$$

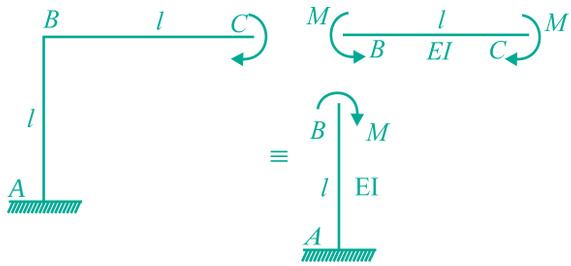
Hence, the correct answer is (D).

3.2 What is the horizontal deflection of free end C of the frame shown in the given figure



(A) $Ml^2/2EI$ (C) Ml^2/EI (C) $3Ml^2/2EI$ (D) $2Ml^2/EI$

Sol. **(A)**



Horizontal deflection of C = horizontal deflection of $B = \dfrac{Ml^2}{2EI}$

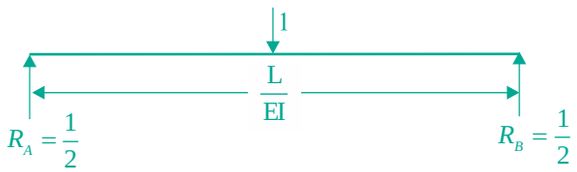
Hence, the correct answer is (A)

ESE 1996

3.3 A simply supported beam of span L and flexural rigidity EI carries a unit point load at its centre. The strain energy in the beam due to bending is

(A) $\dfrac{L^3}{48EI}$ (B) $\dfrac{L^3}{192EI}$ (C) $\dfrac{L^3}{96EI}$ (D) $\dfrac{L^3}{16EI}$

Sol. **(C)**



Strain energy in the beam due to bending,

$$U = \int_0^L \frac{M^2 dx}{2EI} = 2\int_0^{L/2} \frac{(0.5x)^2\, dx}{2EI}$$

$$U = \frac{1}{8EI} \cdot 2\int_0^{L/2} x^2 dx = \frac{1}{4EI}\left[\frac{x^3}{3}\right]_0^{L/2}$$

$$U = \frac{1}{12EI} \times \frac{L^3}{8} = \frac{L^3}{96EI}$$

Hence, the correct answer is (C).

3.4 Which one of the following pairs is not correctly matched?

(A) Lame's constants : Thick cylinder (B) Macaulay's method : Deflection of beam

(C) Euler's method : Theory of column (D) Eddy's theorem : Torsion of shafts

Sol. **(D)**

Eddy's Theorem : Bending moment at a section of a structural element is proportional to the vertical intercept between the pressure line and axis of structure. In case of an arch, the intercept between the arch profile and the pressure line yields the Bending Moment at a section.

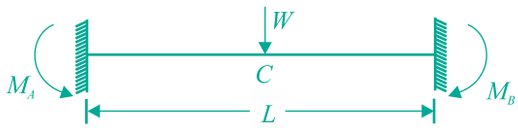
Pressure Line or Line of Thrust : In case the structure has the profile of the force polygon, the B.M. at any section will be zero, the structure in such cases will be subjected only to axial forces. Such as profile along the length of a beam or frame is known as pressure line.

Hence, the correct answer is (D)

3.5 The maximum deflection of a fixed beam carrying a central load W is equal to

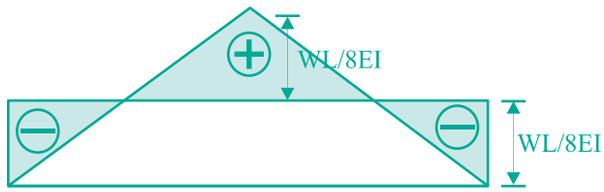
(A) $\frac{WL^3}{48EI}$ (B) $\frac{WL^3}{96EI}$ (C) $\frac{WL^3}{192EI}$ (D) $\frac{5}{384}\frac{WL^3}{EI}$

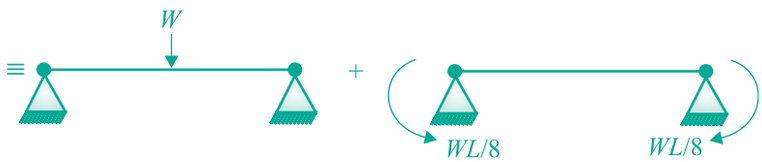
Sol. **(C)**



Fixed End Moments :

$$M_{FAB} = \frac{WL}{8} = M_{FBA}$$





Using moment area method between A & B about C.

$\Delta_c =$ Moment of area of M/EI diagram

$$\Delta_c = \frac{1}{2}\times\frac{L}{2}\times\frac{WL}{4EI}\times\frac{2}{3}\times\frac{L}{2} - \frac{WL}{8EI}\times\frac{L}{2}\times\frac{L}{4}$$

$$\Delta_c = \frac{WL^3}{48EI} - \frac{WL^3}{64EI} = \frac{WL^3}{192EI}$$

Hence, the correct answer is (C).

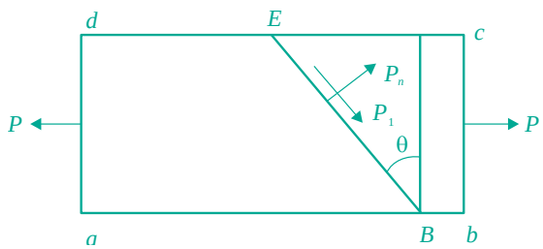
4 Transformation of Stress & Strain

ESE 1995

4.1 The cross-section of a bar is subjected to a uniaxial tensile stress p. The tangential stress on a plane inclined at q to the cross-section of the bar would be

(A) $p \sin 2\theta/2$ (B) $p \sin 2\theta$ (C) $p \cos 2\theta/2$ (D) $p \cos 2\theta$

Sol. **(A)**



On plane BE normal stress (P_n) and tangential stress (P_t) are induced

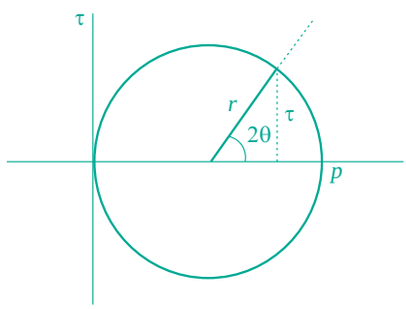
Tangential stress on plane $BE = (P_t) = \dfrac{\text{Tangential force along plane BE}}{\text{Sectional area along plane BE}}$

$$= \frac{PA\sin\theta}{A\sec\theta} = P\sin\theta\cos\theta = \frac{P}{2}\sin 2\theta$$

Hence, the correct option is (A).

Alternative :

Using Mohr Circle



$$r = \frac{p-0}{2} = \frac{p}{2}$$

Tangential stress $= \tau = r \sin 2\theta = \frac{p}{2} \sin \theta$

Hence, the correct option is (A).

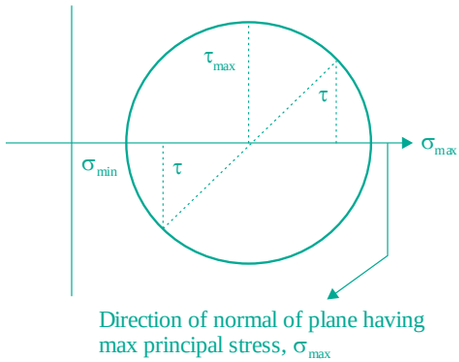
4.2 Consider the following statements:

1. On planes having maximum and minimum principal stresses, there will be no tangential stress.
2. Shear stresses on mutually perpendicular planes are numerically equal.
3. Maximum shear stress is equal to half the sum of the maximum and minimum principal stresses.

Of these statements

(A) 1, 2 and 3 are correct
(B) 1 and 2 are correct
(C) 2 and 3 are correct
(D) 1 and 3 are correct

Sol. **(B)**



From Mohr Circle :

- Plane having principal stress has no tangential stress.
- Mutually perpendicular planes $(\theta = 90^0)$ are 180^0 apart in mohr circle and have numerically equal value of shear stress.
- $\tau_{max} = \frac{\sigma_{max} - \sigma_{min}}{2}$

Hence, the correct option is (B).

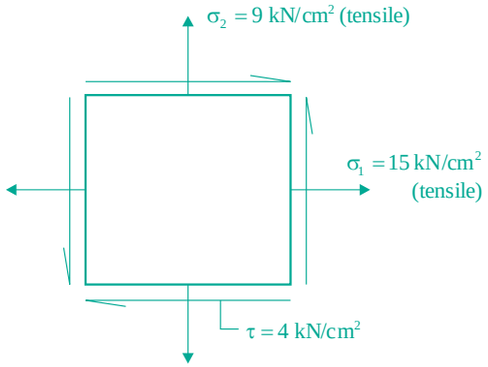
4.3 In a stressed body, an elementary cube of material is taken at a point with its faces perpendicular to x and y reference axes. Tensile stresses equal to 15 kN/cm^2 and 9 kN/cm^2 are observed on these respective faces. They are also accompanied by shear stresses equal to 4 kN/cm^2. The magnitude of the principal

stresses at the point are

(A) 12 kN/cm^2 tensile and 3 kN/cm^2 tensile
(B) 17 kN/cm^2 tensile and 7 kN/cm^2 tensile
(C) 9.5 kN/cm^2 compressive and 6.5 kN/cm^2 compressive
(D) 19 kN/cm^2 tensile and 13 kN/cm^2 tensile

Sol. **(B)**

$$\sigma_{max} = \frac{\sigma_1+\sigma_2}{2} + \sqrt{\left(\frac{\sigma_1-\sigma_2}{2}\right)^2 + \tau^2} = \frac{15+9}{2} + \sqrt{\left(\frac{15-9}{2}\right)^2 + 4^2}$$



$$\sigma_{max} = 12+5 = 17\,\text{kN/cm}^2 \text{ (tensile)}$$

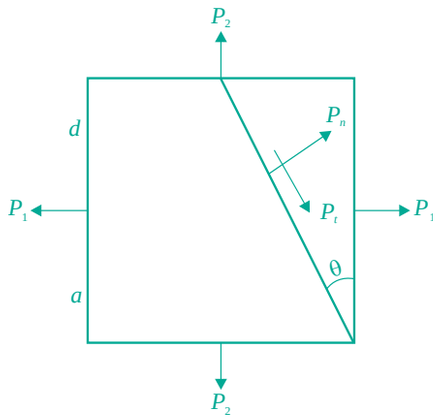
$$\sigma_{min} = \frac{\sigma_1+\sigma_2}{2} - \sqrt{\left(\frac{\sigma_1-\sigma_2}{2}\right)^2 + \tau^2} = 12-5 = 17\,\text{kN/cm}^2 \text{ (tensile)}$$

Hence, the correct option is (B).

4.4 In a rectangular element subjected to like principal tensile stresses p_1 and p_2 in two mutually perpendicular directions x and y, the maximum shear stress would occur along the

(A) Plane normal to x-axis
(B) Plane normal to y-axis
(C) Plane at 45^0 to y-direction
(D) Planes at 45^0 and 135^0 to y-direction

Sol. **(D)**



Tangential or shear stress, $P_t = \frac{P_1-P_2}{2}\sin 2\theta$

For P_t to be maximum, $\sin 2\theta = 1$

$$2\theta = 90^0 \text{ or } 270^0$$

$$\theta = 45^0 \text{ or } 135^0$$

Hence, the correct option is (D).

5 Combined Stresses

ESE 1995

5.1 At a point in a structure, there are two mutually perpendicular tensile stresses of $800\ \text{kg/cm}^2$ and $400\ \text{kg/cm}^2$. If the Poisson's ratio is $\mu = 0.25$, what would be the equivalent stress in simple tension according to Maximum Principal Strain Theory?

(A) $1200\ \text{kg/cm}^2$ (B) $900\ \text{kg/cm}^2$ (C) $700\ \text{kg/cm}^2$ (D) $400\ \text{kg/cm}^2$

Sol. **(C)**

As per maximum principal strain theory,

$$\varepsilon_{max} = \frac{\sigma_x}{E} - \frac{\mu\sigma_y}{E}$$

$$\frac{\sigma}{E} = \frac{800}{E} - \frac{0.25 \times 400}{E}$$

$$\sigma = 800 - 100 = 700\ \text{kg/cm}^2$$

Hence, the correct option is (C).

5.2 According to maximum shear stress failure criterion, yielding in material occurs when

(A) Maximum shear stress $= \frac{1}{2} \times$ yield stress (B) Maximum shear stress $= \sqrt{2} \times$ yield stress

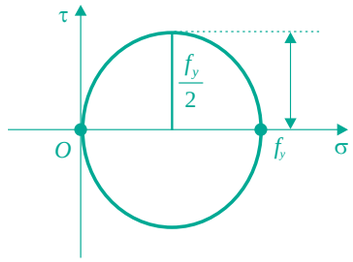
(C) Maximum shear stress $= \sqrt{\frac{2}{3}} \times$ yield stress (D) Maximum shear stress $= 2 \times$ yield stress

Sol. **(A)**

According to maximum shear stress theory, for no failure maximum shear stress should be less than or equal to maximum shear stress under uniaxial loading.

For yielding in material :

$$\text{Maximum shear stress} = \frac{1}{2} \text{ yield stress}$$



Hence, the correct option is (A).

5.3 A rectangular block of size $200\text{ mm}\times100\text{ mm}\times50\text{ mm}$ is subjected a shear stress of 500 kg/cm^2. If the modulus of rigidity of the material is $1\times10^6\text{ kg/cm}^2$, the strain energy stored will be

(A) 1000 kg cm (B) 500 kg cm (C) 125 kg cm (D) 100 kg cm

Sol. **(C)**

Strain energy per unit volume $=\frac{1}{2}$ shear stress$\times$Shear strain

$$\frac{U}{v}=\frac{1}{2}\times\tau\times\frac{\tau}{G}=\frac{1}{2}\times\frac{(500)^2}{10^6}$$

$$U=0.125\times20\times10\times5=125\text{ kg-cm}$$

Hence, the correct option is (C).

5.4 A shaft is subjected to a bending moment M and a torque T. The equivalent bending moment 'M_{eq}' on the shaft is given by

(A) $\frac{M+\sqrt{M^2+T^2}}{4}$ (B) $\frac{M^2+\sqrt{M+T}}{2}$ (C) $\frac{M-\sqrt{M^2+T^2}}{2}$ (D) $\frac{M+\sqrt{M^2+T^2}}{2}$

Sol. **(D)**

Due to Bending maximum normal stress, $\sigma=\frac{My}{I}=\frac{M.D/2}{\pi D^4/64}=\frac{32M}{\pi D^3}$

Due to torsion maximum shear stress, $\tau=\frac{Tr}{J}=\frac{T.D/2}{\pi D^4/32}=\frac{16T}{\pi D^3}$

Maximum normal stress due to combined action of bending and torsion,

$$\sigma_{max}=\frac{\sigma}{2}+\sqrt{\left(\frac{\sigma}{2}\right)^2+\tau^2}$$

$$\frac{32M_e}{\pi D^3}=\frac{16M}{\pi D^3}+\sqrt{\left(\frac{16M}{\pi D^3}\right)^2+\left(\frac{16T}{\pi D^3}\right)^2}$$

$$M_e=\frac{1}{2}\left[M+\sqrt{M^2+T^2}\right]$$

Hence, the correct option is (D).

6 Bending Stress in Beams

ESE 1995

6.1 A steel wire of 20 mm diameter is bent into a circular shape of 10 m radius. If E, the modulus of elasticity is 2×10^6 kg/cm^2 then the maximum stress induced in the wire is

(A) 10^3 kg/cm^2 (B) 2×10^3 kg/cm^2 (C) 4×10^3 kg/cm^2 (D) 6×10^3 kg/cm^2

Sol. **(B)**

From flexure formula, $\frac{M}{I}=\frac{f}{y}=\frac{E}{R}$

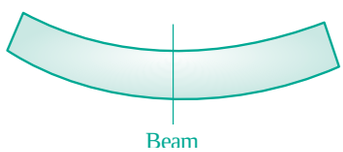
$$\frac{f}{y}=\frac{E}{R}$$

$$\frac{f_{max}}{(2/2)}=\frac{2\times10^6}{1000} \qquad \{\text{for } y\to y_{max} \text{ and } f\to f_{max}\}$$

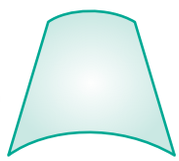
$$f_{max}=2\times10^3 \text{ kg/cm}^2$$

Hence, the correct option is (B).

6.2 For a square-section beam bent as shown in the given figure, the exaggerated view of the deformed cross-section is



(A) 

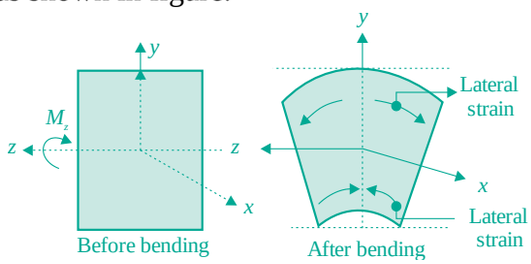
(B) 

(C) 

(D) 

Sol. **(C)**

Due to poisson's effect, longitudinal strain leads to lateral strain. Hence a rectangular *x*-section will deform and will take a shape as shown in figure.



Hence, the correct option is (C).

6.3 Consider the following statements :

1. If a beam has two axes of symmetry even then shear centre does not coincide with the centroid.
2. For a section having one axis of symmetry, the shear centre does not coincide with the centroid but lies on the axis of symmetry.
3. If a load passes through the shear centre, then there will be only bending in the cross-section and no twisting.

Which of these statements are correct?

(A) 1, 2 and 3 (B) 1 and 2 (C) 2 and 3 (D) 1 and 3

Sol. **(C)**

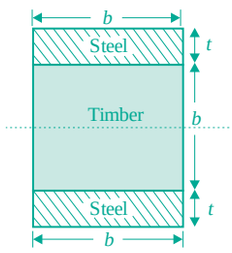
- If axis of symmetry is present, the shear centre (like the centroid) lies on axis of symmetry and therefore the shear centre and the centroid coincide for a doubly symmetric cross section
- If a beam has singly symmetric cross section, both the centroid and shear centre lie on the axis of symmetry.
- If load passes through the shear centre, then there will be no twisting.

Hence, the correct option is (C).

6.4 Given that, $m = \frac{E_s}{E_t}$, $I_t =$ Moment of Inertia of Timber portion and $I_s =$ Moment of inertia of steel portion, the equivalent moment of inertia of a flitched beam made of steel and timber is given by

(A) $I_t + \frac{I_s}{m}$ (B) $I_s + \frac{I_t}{m}$ (C) $I_s + mI_t$ (D) $I_t + mI_s$

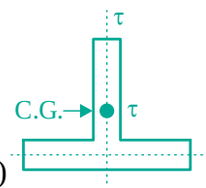
Sol. **(B, D)**

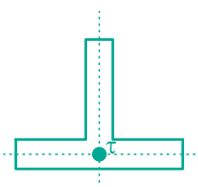


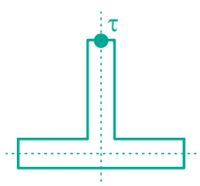
7 Shear Stress in Beams

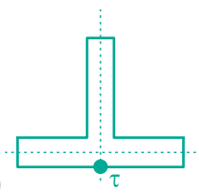
ESE 1995

7.1 In a thin-walled *T*-section, the shear centre *C* is located at the point shown in

(A) 

(B) 

(C) 

(D) 

Sol. **(B)**

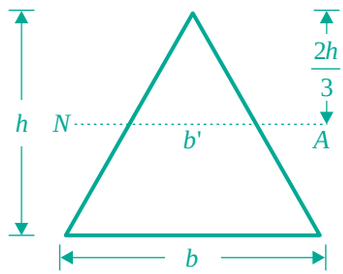
Shear centre of sections consisting of two intersecting narrow rectangles always lies at the intersection of centre lines of two rectangles.

Hence, the correct option is (B).

7.2 A beam has a triangular cross-section, having base '*b*' and altitude '*h*'. If a section of the beam is subjected to a shear force F, the shear stress at the level of neutral axis in the cross-section is given by

(A) $\frac{4}{3}\frac{F}{bh}$ (B) $\frac{3}{4}\frac{F}{bh}$ (C) $\frac{8}{3}\frac{F}{bh}$ (D) $\frac{3}{8}\frac{F}{bh}$

Sol. **(C)**



Shear stress at the level of NA, $\tau = \frac{vA\bar{y}}{lb}$

Where, v = Shear force at the section, $(A\bar{y})$ = First moment of area of portion above the level at which shear stress is to be found out, I = Moment of inertia of complete section about N. A., b = Width of location where shear stress is to be found out.

$$\therefore \quad \tau = \frac{F \times \left(\frac{1}{2} \times \frac{2}{3} b \times \frac{2h}{3} \times \frac{1}{3} \times \frac{2h}{3}\right)}{\frac{bh^3}{36} \times \frac{2}{3} b} = \frac{8}{3} \times \frac{F}{bh}$$

Hence, the correct option is (C).

ESE 1996

7.3 **Assertion (A) :** A beam of circular cross-section in comparison to rectangular section of the same material but of equal cross-sectional area can resist a large shear force.

Reason (R) : The maximum intensities of shear stress in the section of a beam of circular cross section and of a rectangular cross-section are $1\frac{1}{3}$ times and $1\frac{1}{2}$ times the average shear stress respectively.

(A) Both A and R are true and R is correct explanation of A

(B) Both A and R are true but R is not a correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

Sol. **(A)**

Let τ_{max} be the maximum permissible shear stress in the material.

For rectangular section, $\frac{3V_R}{2A} = \tau_{max}$

$$V_R = \frac{2A\tau_{max}}{3}$$

For circular section, $\frac{4V_C}{3A} = \tau_{max}$

$$V_c = \frac{3A\tau_{max}}{4}$$

$$V_c > V_R$$

Thus, circular section can resist a larger shear force than rectangular section.

Hence, the correct option is (A).

7.4 Consider the following statements :

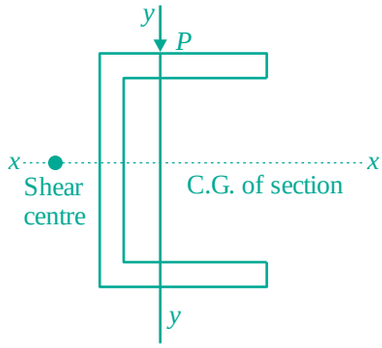
A beam of channel cross-section with vertical web loaded with a concentratcd load at mid-span in a plane perpendicular to the plane of symmetry passing through the centroid is subjected to

1. Bending moment
2. Twisting moment
3. Shear force
4. Axial thrust

Which of these statements are correct?

(A) 2, 3 and 4 (B) 1, 2 and 3 (C) 1 and 2 (D) 1 and 3

Sol. **(B)**



Due to load, the channel section will have bending and shear also the load is not passing through shear centre so there will be twisting moment.

Hence, the correct option is (B).

ESE 1997

7.5 The shear centre of a section is defined as that point

(A) Through which the load must be applied to produce zero twisting moment on the section

(B) At which the shear force is zero

(C) At which the shear force is a maximum

(D) At which the shear force is a minimum

Sol. **(A)**

Shear centre of a section is the centroid of all the shear forces in the section that's why if load is applied at shear centre it produces zero twisting moment.

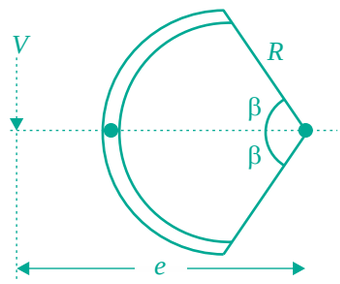
Hence, the correct option is (A).

ESE 1998

7.6 Shear centre of a semi-circular arc strip of radius 'R' will be at a distance of X from the centre of

(A) $\frac{\pi R}{2}$ (B) $\frac{2R}{\pi}$ (C) $\frac{4R}{\pi}$ (D) $\frac{\pi R}{4}$

Sol. **(C)**



$$e = \frac{2R(\sin\beta - \beta\cos\beta)}{\beta - \sin\beta\cos\beta}$$ where $\beta = \frac{\pi}{2}$, we have semicircular arc.

8 Torsion of Circular Shaft

ESE 1995

8.1 A solid shaft of circular cross-section is subjected to a torque T which produces a maximum shear stress f_s in the shaft. The diameter of the shaft should be

(A) $\sqrt{\frac{\pi f_s}{16T}}$ (B) $3\sqrt{\frac{\pi f_s}{16T}}$ (C) $\sqrt{\frac{16T}{\pi f_s}}$ (D) $3\sqrt{\frac{16T}{\pi f_s}}$

Sol. **(D)**

From Torsion Formula, $\frac{T}{J}=\frac{\tau}{r}=\frac{G\phi}{L}$

For circular shaft, $J=\frac{\pi d^4}{32}, r=\frac{d}{2}$

$$\frac{32T}{\pi d^4}=\frac{f_s}{d/2}$$

$$d=\left(\frac{16T}{\pi f_s}\right)^{\frac{1}{3}}=3\sqrt{\frac{16T}{\pi f_s}}$$

Hence, the correct option is (D).

ESE 1997

8.2 If the diameter of a shaft subjected to torque alone is doubled, then the horse power P can be increased to

(A) 16 P (B) 8 P (C) 4 P (D) 2P

Sol. **(B)**

Power = Torque $\times$ Angular velocity

$P \propto$ Torque

From Torsion Formula, $\frac{\tau}{r}=\frac{T}{J}$

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

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

$$\frac{T_1}{T_2} = \left(\frac{d_1}{d_2}\right)^3$$

$$T_2 = T_1\left(\frac{2}{1}\right)^3 = 8T$$

If diameter of shaft is doubled, toque can be increased to 8 times hence power can be increased to 8 times.

Hence, the correct option is (B).

ESE 1998

8.3 Two shafts of solid circular cross-section are identical except for their diameters 'd_1' and 'd_2'. They are subjected to the same torque 'T'. The ratio of the strain energies stored $\frac{U_1}{U_2}$, will be

(A) $\left(\frac{d_1}{d_2}\right)^4$ (B) $\left(\frac{d_1}{d_2}\right)^2$ (C) $\left(\frac{d_2}{d_1}\right)^2$ (D) $\left(\frac{d_2}{d_1}\right)^4$

Sol. **(D)**

Strain energy stored due to torsion, $U = \frac{T^2 L}{2GJ}$

$$\frac{U_1}{U_2} = \frac{J_2}{J_1} = \frac{\pi d_2^4/32}{\pi d_1^4/32} = \left(\frac{d_2}{d_1}\right)^4$$

Hence, the correct option is (D).

8.4 Consider the following statements :

If a solid circular shaft and a hollow circular shaft have the same torsional strength, then

1. The weight of the hollow shaft will be less than that of the solid shaft.
2. The external diameter of the hollow shaft will be greater than that of the solid shaft.
3. The stiffness of the hollow shaft will be equal to that of the solid shaft.

Of these statements.

(A) 1, 2, and 3 are correct (B) 2 and 3 are correct

(C) 1 alone is correct (D) 1 and 2 are correct

Sol. **(D)**

Diameter of solid circular shaft is d_s and diameters of hollow circular shaft are d_1 and d_2 (where $d_1 > d_2$)

From torsion formula, $\frac{\tau}{r} = \frac{T}{J} = \frac{G\theta}{L}$

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

For the same material and same torsional strength τ_{max} and T and same in both the shaft.

$\therefore$ $$\tau_{max} = \frac{T\left(\frac{d_s}{2}\right)}{\frac{\pi d_s^4}{32}} = \frac{T\left(\frac{d_1}{2}\right)}{\frac{\pi}{32}(d_1^4 - d_2^4)}$$

$$\frac{d_s}{d_s^4} = \frac{d_s}{d_1^4 - d_2^4} \qquad \ldots(i)$$

$$d_s^3 = d_1^3 - \left(\frac{d_2}{d_1}\right)^4$$

$$d_1 > d_s$$

External dia. of hollow shaft is greater than solid shaft.

From eq. (i) $$\frac{d_s^4}{d_s} = \frac{d_1^4 - d_2^4}{d_1} = \frac{(d_1^2 - d_2^2)(d_1^2 + d_2^2)}{d_1}$$

$$d_s \cdot A_s = A_H\left(\frac{d_1^2 + d_2^2}{d_1}\right)$$

$$A_s = \frac{A_H\left(d_1 + \frac{d_2^2}{d_1}\right)}{d_s} = kA_H$$

$\because$ $$d_1 > d_s$$

$\therefore$ $$\left(d_1 + \frac{d_2^2}{d_1}\right) > d_s \Rightarrow K > 1$$

$\therefore$ $$A_H < A_s$$

$\because$ Weight of shaft $= A \times r \times L$

Or Weight $\propto A$

Thus, weight of hollow shaft is less than solid shaft.

Stiffness of shaft, $$\frac{T}{\theta} = \frac{GJ}{L}$$

For the same length of shaft and same G, $\frac{T}{\theta} \propto J$

$\therefore$ $$\frac{(\text{Stiffness})_{hollow}}{(\text{Stiffness})_{solid}} = \frac{\pi(d_1^4 - d_2^4)/32}{\pi d_s^4/32} = \frac{(d_1^4 - d_2^4)}{d_s^4} = \frac{d_1}{d_s} > 1$$ [From equation (i)]

Thus, stiffness of hollow shaft is greater than the stiffness of solid shaft.

Hence, the correct option is (D).

9 Columns

ESE 1995

9.1 If the crushing stress in the material of a mild steel column is 3300 kg/cm^2, Euler's formula for crippling load is applicable for slenderness ratio equal to/greater than

(A) 40 (B) 50 (C) 60 (D) 80

Sol. **(D)**

Euler's formula is applicable for long columns.

The buckling stress $\frac{\pi^2 E}{\lambda^2}$ should be less than crushing stress

$$\frac{\pi^2 E}{\lambda^2} \le 3300\,\text{kg/cm}^2$$

$$\frac{\pi^2 \times 2\times 10^5\,\text{N/mm}^2}{\lambda^2} \le 330\,\text{N/mm}^2$$

$$\lambda \ge \sqrt{\frac{\pi^2 \times 2\times 10^5}{330}} \ge 77.34$$

Hence, the correct option is (D).

9.2 Which one of the following pairs is not correctly matched?

Boundary conditions column	Euler's buckling load
(a) Pin-Pin	$\pi^2 EI/L^2$
(b) Fixed-Fixed	$4\pi^2 EI/L^2$
(c) Fixed-Free	$0.25\pi EI/L^2$
(d) Fixed-Pin	$\sqrt{2}\pi EI/L^2$

Sol. **(D)**

Boundary condition	Euler buckling load
	$P = \frac{\pi^2 EI}{(L_{effective})^2}$
Pin-Pin	$P = \frac{\pi^2 EI}{(L^2)} = \frac{\pi^2 EI}{L^2}$

Fixed-Fixed	$P=\dfrac{\pi^2 EI}{\left(\frac{L}{2}\right)^2}=\dfrac{4\pi^2 EI}{L^2}$
Fixed-Free	$P=\dfrac{\pi^2 EI}{(2L)^2}=\dfrac{0.25\pi^2 EI}{L^2}$
Fixed-Pin	$P=\dfrac{\pi^2 EI}{\left(\frac{L}{\sqrt{2}}\right)^2}=\dfrac{2\pi^2 EI}{L^2}$

Hence, the correct option is (D).

9.3 The resultant cuts the base of a circular column of diameter '*d*' with an eccentricity equal to *d*/4. The ratio between the maximum compressive stress and the maximum tensile stress is

(A) 3 (B) 4 (C) 5 (D) infinity

Sol. **(A)**

Let Resultant *P* is acting at an eccentricity $e=\dfrac{d}{4}$

Maximum tensile stress, $\sigma_t=\dfrac{M_y}{I}-\dfrac{P}{A}=\dfrac{Pe\cdot y}{I}-\dfrac{P}{A}$

$$\sigma_t=\frac{P\left(\frac{d}{4}\right)\cdot\left(\frac{d}{2}\right)}{\left(\frac{\pi d^4}{64}\right)}-\frac{P}{\left(\frac{\pi d^2}{4}\right)}=\frac{8P}{\pi d^2}-\frac{4P^2}{\pi d^2}=\frac{4P}{\pi d^2}$$

Maximum compressive stress, $\sigma_c=\dfrac{M_y}{I}+\dfrac{P}{A}=\dfrac{8P}{\pi d^2}+\dfrac{4P}{\pi d^2}=\dfrac{12P}{\pi d^2}$

$$\frac{\sigma_c}{\sigma_t}=\frac{\left(\frac{12P}{\pi d^2}\right)}{\left(\frac{4P}{\pi d^2}\right)}=3$$

Hence, the correct option is (A).

Alternative :

For circular cross section, $\sigma_{max/min}=\dfrac{4P}{\pi d^2}\left[1\pm\dfrac{8e}{d}\right]$

Given : $e=\dfrac{d}{4}$

$$\frac{\sigma_{max}}{\sigma_{min}}=\frac{1+\frac{8e}{d}}{1-\frac{8e}{d}}=\frac{1+2}{1-2}=-3$$

10 Springs

ESE 1995

10.1 If two springs of stiffness K_1 and K_2 are connected in series, the stiffness of the combined spring is

(A) $\frac{K_1K_2}{K_1+K_2}$ (B) $\frac{K_1+K_2}{K_1K_2}$ (C) K_1+K_2 (D) K_1K_2

Sol. **(A)**

Total stiffness = K

Deflection of combined system, $\Delta = \Delta_1 + \Delta_2$

$$\frac{F}{K} = \frac{F}{K_1} + \frac{F}{K_2}$$

$$K = \frac{K_1K_2}{K_1+K_2}$$

Hence, the correct option is (A).

ESE 1996

10.2 Two closed springs of stiffness 'K' and '2K' are arranged in series in one case and in parallel in the other case. The ratio of stiffness of springs connected in series to parallel is

(A) $\frac{1}{3}$ (B) $\frac{1}{9}$ (C) $\frac{2}{3}$ (D) $\frac{2}{9}$

Sol. **(D)**

$$K_1 = K \text{ and } K_2 = 2K$$

When springs are connected in series, $\frac{1}{K_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$

$$\frac{1}{K_{eq}} = \frac{1}{k} + \frac{1}{2k} = \frac{3}{2k} \Rightarrow K_{eq} = \frac{2K}{3}$$

When springs are connected in parallel, $K_{eq} = k_1 + k_2 = K + 2K = 3K$

$$\therefore \quad \frac{(K_{eq})_{series}}{(K_{eq})_{parallel}} = \frac{\left(\frac{2K}{3}\right)}{3K} = \frac{2}{9}$$

Hence, the correct option is (D).

ESE 1998

10.3

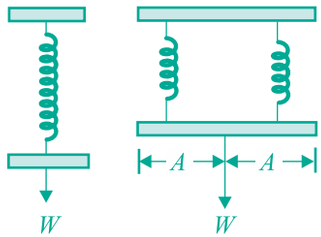


Fig - I Fig - II

A close-coiled helical spring shown above in figure-I is to be cut into two equal pieces and combined as a parallel spring as shown in figure-II. The ratio of the maximum angular twist of the situation shown in figure-II to that of Figure-I, due to same load '*W*' will be

(A) 1 (B) 1/2 (C) 1/4 (D) 1/8

Sol. (C)

$$\frac{T}{\theta} = \frac{GJ}{L}$$

$$T = W \times R$$

$$J = \frac{rd^4}{32}$$

$$\theta = \frac{TL}{aJ} = \frac{WRL}{\frac{rd^4}{32}G}$$

$$\theta_{II} = \frac{32WRL}{rd^4G} = \frac{32\left(\frac{W}{2}\right)R\left(\frac{L}{2}\right)}{rd^4G}$$

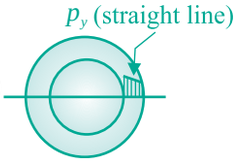
$$\frac{\theta_{II}}{\theta_I} = \frac{32\left(\frac{W}{2}\right)R\left(\frac{L}{2}\right)}{\frac{rd^4G}{32WRL}} = \frac{1}{4}$$

Hence, the correct option is (C).

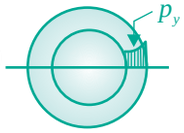
11 Thick & Thin Cylinder/ Sphere

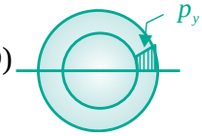
ESE 1995

11.1 A thick cylindrical pressure vessel of inner diameter D_1 and outer diameter D_0 is subjected to an internal fluid pressure of intensity p. The variation of the circumferential tensile stress P_y in the thickness of the shell will be

(A) 

(B) 

(C) 

(D) 

Sol. **(B)**

Variation of circumferential tensile stress (hoop stress) is given by Lame's theorem.

$$\sigma_n = \frac{B}{R^2} + A$$

where A and B are positive constant and R is (Distance of Annular Ring) the radius from centre as the R will increase, σ_h will decrease hyperbolically.

Note : Radial pressure : $\sigma_R = \frac{B}{R^2} - A$

Value of A and B is calculated from boundary condition :

At $R = R_i$, $\sigma_R = P$

At $R = R_0$, $\sigma_R = 0$

Hence, the correct option is (B).

11.2 A thin cylindrical steel pressure vessel of diameter 6 cm and wall thickness 3 mm is subjected to an internal fluid pressure of intensity p. If the ultimate strength of steel is 3600 kg/cm^2, the bursting pressure will be

(A) 18 kg/ cm^2 (B) 36 kg/ cm^2 (C) 180 kg/ cm^2 (D) 18 kg/ cm^2

Sol. **(D)**

Hoop stress, $\sigma_h = \frac{Pd}{4t}$

Longitudinal stress, $\sigma_l = \frac{Pd}{4t}$

Hoop stress > Longitudinal stress

So, $\frac{Pd}{2t}$ = Ultimate strength of steel vessel

$$\frac{P \times 6}{2 \times 0.3} = 3600$$

$$P = 360\,\text{kg/cm}^2$$

Hence, the correct option is (D).

ESE 1996

11.3 Two closed thin vessels, one cylindrical and the other spherical with equal internal diameter and wall thickness are subjected to equal internal fluid pressure. The ratio of hoop stresses in the cylindrical to that of spherical vessel is

(A) 4.0 (B) 2.0 (C) 1.0 (D) 0.5

Sol. **(B)**

Hoop stress in cylinder, $\sigma_1 = \frac{pd}{2t}$

Hoop stress in sphere, $\sigma_2 = \frac{pd}{4t}$

So, $\frac{\sigma_1}{\sigma_2} = 2$

Hence, the correct option is (B).

ESE 1997

11.4 A thin cylindrical shell of internal diameter 'D' and thickness 't' is subjected to internal pressure 'p'. The change in diameter is given by

(A) $\frac{pD^2}{4tE}(2-\mu)$ (B) $\frac{pD^2}{4tE}(1-2\mu)$ (C) $\frac{pD^2}{2tE}(1-2\mu)$ (D) $\frac{pD^2}{2tE}(2-\mu)$

Sol. **(A)**

Hoop stress, $\sigma_h = \frac{pd}{2t}$

Longitudinal stress, $\sigma_l = \frac{pd}{4t}$

Hoop strain, $\varepsilon_n = \frac{\sigma_n}{\varepsilon} - \frac{\mu\sigma_l}{\varepsilon} = \frac{pD}{4tE}[2-\mu]$

Hoop strain is along the circumference,

$\therefore$ $\varepsilon_n = \frac{\text{Change in perimeter}}{\text{Perimeter}} = \frac{\pi\Delta D}{\pi D} = \frac{\Delta D}{D}$

ESE 2026

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A. Stage-I (Preliminary/Stage-I) Examination :

Subject	Duration	Maximum Marks
Category - I Civil Engineering		
Paper-I (General Studies and Engineering Aptitude)	2 hrs.	200
Paper-II (Civil Engineering)	3 hrs.	300
Total		500

B. Stage-II (Main/Stage-II) Examination :

Subject	Duration	Maximum Marks
Category - I Civil Engineering		
Paper-I (Civil Engineering)	3 hrs.	300
Paper-II (Civil Engineering)	3 hrs.	300
Total		600

Syllabus

Paper-I Syllabus :

Contents for syllabi of both the Papers together for Preliminary Examination/Stage-I (objective type Paper–II) and separately for Main/Stage-II Examination (Conventional type Paper-I and Paper – II).

1. **Building Materials :** Stone, Lime, Glass, Plastics, Steel, FRP, Ceramics, Aluminum, Fly Ash, Basic Admixtures, Timber, Bricks and Aggregates: Classification, properties and selection criteria;
   Cement : Types, Composition, Properties, Uses, Specifications and various Tests; Lime & Cement Mortars and Concrete: Properties and various Tests; Design of Concrete Mixes: Proportioning of aggregates and methods of mix design.
2. **Solid Mechanics :** Elastic constants, Stress, plane stress, Strains, plane strain, Mohr's circle of stress and strain, Elastic theories of failure, Principal Stresses, Bending, Shear and Torsion.
3. **Structural Analysis :** Basics of strength of materials, Types of stresses and strains, Bending moments and shear force, concept of bending and shear stresses; Analysis of determinate and indeterminate structures; Trusses, beams, plane frames; Rolling loads, Influence Lines, Unit load method & other methods; Free and Forced vibrations of single degree and multi degree freedom system; Suspended Cables; Concepts and use of Computer Aided Design.
4. **Design of Steel Structures :** Principles of Working Stress methods, Design of tension and compression members, Design of beams and beam column connections, built-up sections, Girders, Industrial roofs, Principles of Ultimate load design.
5. **Design of Concrete and Masonry Structures :** Limit state design for bending, shear, axial compression and combined forces; Design of beams, Slabs, Lintels, Foundations, Retaining walls, Tanks, Staircases; Principles of pre-stressed concrete design including materials and methods; Earthquake resistant design of structures; Design of Masonry Structure.
6. **Construction Practice, Planning and Management :** Construction - Planning, Equipment, Site investigation and Management including Estimation with latest project management tools and network analysis for different Types of works; Analysis of Rates of various types of works; Tendering Process and Contract Management, Quality Control, Productivity, Operation Cost; Land acquisition; Labour safety and welfare.

Paper-II Syllabus :

1. **Flow of Fluids, Hydraulic Machines and Hydro Power :**
   (a) **Fluid Mechanics, Open Channel Flow, Pipe Flow :** Fluid properties; Dimensional Analysis and Modeling; Fluid dynamics including flow kinematics and measurements; Flow net; Viscosity, Boundary layer and control, Drag, Lift, Principles in open channel flow, Flow controls. Hydraulic jump; Surges; Pipe networks.
   (b) **Hydraulic Machines and Hydro power :** Various pumps, Air vessels, Hydraulic turbines – types, classifications & performance parameters; Power house –classification and layout, storage, pondage, control of supply.

2. **Hydrology and Water Resources Engineering :** Hydrological cycle, Ground water hydrology, Well hydrology and related data analysis; Streams and their gauging; River morphology; Flood, drought and their management; Capacity of Reservoirs.

   Water Resources Engineering : Multipurpose uses of Water, River basins and their potential; Irrigation systems, water demand assessment; Resources - storages and their yields; Water logging, canal and drainage design, Gravity dams, falls, weirs, Energy dissipaters, barrage Distribution works, Cross drainage works and head-works and their design; Concepts in canal design, construction & maintenance; River training, measurement and analysis of rainfall.

3. **Environmental Engineering :**

   (a) **Water Supply Engineering :** Sources, Estimation, quality standards and testing of water and their treatment; Rural, Institutional and industrial water supply; Physical, chemical and biological characteristics and sources of water, Pollutants in water and its effects, Estimation of water demand; Drinking water Standards, Water Treatment Plants, Water distribution networks.

   (b) **Waste Water Engineering :** Planning & design of domestic waste water, sewage collection and disposal; Plumbing Systems. Components and layout of sewerage system; Planning & design of Domestic Waste-water disposal system; Sludge management including treatment, disposal and re-use of treated effluents; Industrial waste waters and Effluent Treatment Plants including institutional and industrial sewage management.

   (c) **Solid Waste Management :** Sources & classification of solid wastes along with planning & design of its management system; Disposal system, Beneficial aspects of wastes and Utilization by Civil Engineers.

   (d) **Air, Noise pollution and Ecology :** Concepts & general methodology.

4. **Geo-technical Engineering and Foundation Engineering :**

   (a) **Geo-technical Engineering :** Soil exploration - planning & methods, Properties of soil, classification, various tests and interrelationships; Permeability & Seepage, Compressibility, consolidation and Shearing resistance, Earth pressure theories and stress distribution in soil; Properties and uses of geo-synthetics.

   (b) **Foundation Engineering :** Types of foundations & selection criteria, bearing capacity, settlement analysis, design and testing of shallow & deep foundations; Slope stability analysis, Earthen embankments, Dams and Earth retaining structures: types, analysis and design, Principles of ground modifications.

5. **Surveying and Geology :**

   (a) **Surveying :** Classification of surveys, various methodologies, instruments & analysis of measurement of distances, elevation and directions; Field astronomy, Global Positioning System; Map preparation; Photogrammetry; Remote sensing concepts; Survey Layout for culverts, canals, bridges, road/railway alignment and buildings, Setting out of Curves.

   (b) **Geology :** Basic knowledge of Engineering geology & its application in projects.

6. Transportation Engineering :

Highways : Planning & construction methodology, Alignment and geometric design; Traffic Surveys and Controls; Principles of Flexible and Rigid pavements design.

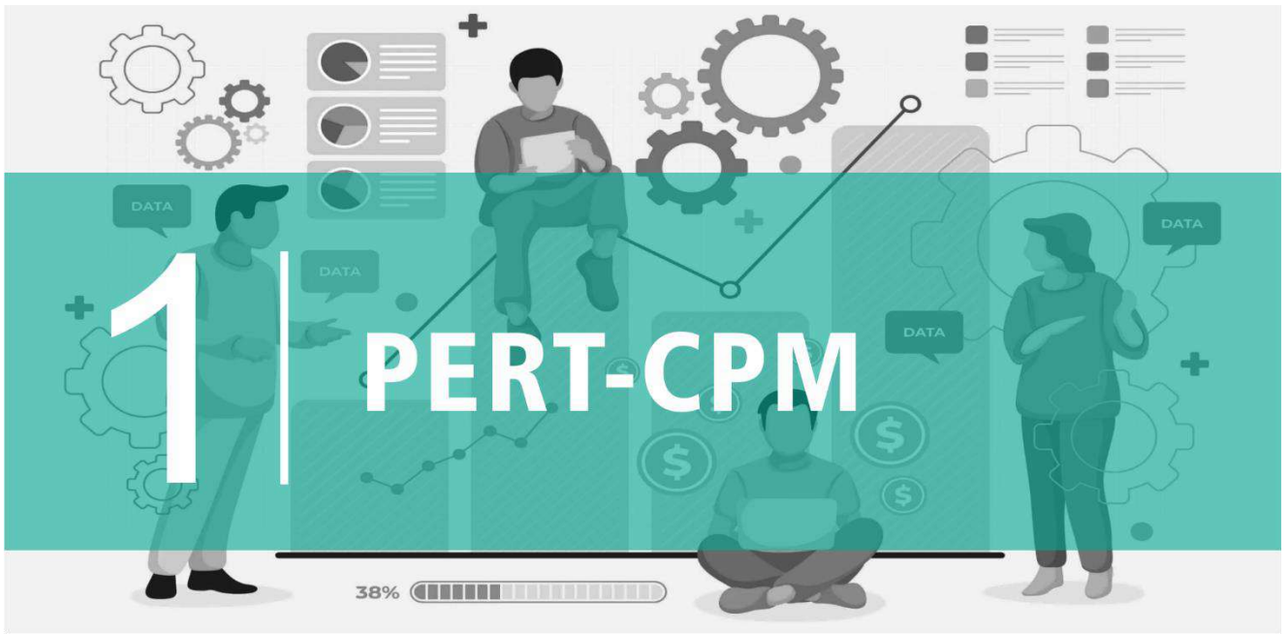
Tunneling : Alignment, methods of construction, disposal of muck, drainage, lighting and ventilation.

Railways Systems : Terminology, Planning, designs and maintenance practices; track modernization.

Harbours : Terminology, layouts and planning.

Airports : Layout, planning & design.

CONTENT



Syllabus : PERT-CPM

Concreting Equipment : Weight Batcher, Mixer, vibrator, batching plant, concrete pump. Cranes, hoists, lifting equipments.

Earthwork Equipment : Power shovel, hoe, dozer, dumper, trailers and tractor, rollers, sheep foot rollers, pumps.

Construction, Planning and Management : Bar chart, linked bar chart, work-break down structures, Activity - on - arrow diagrams. Critical path, probabilistic activity durations; Event-based networks.

PERT Network : Time-cost study, crashing; Resource allocation.

Contents : PERT-CPM

1 Project Management

ESE 1997

1.1 Gantt charts indicate

(A) Comparison of actual progress with the scheduled progress

(B) Balance of work to be done

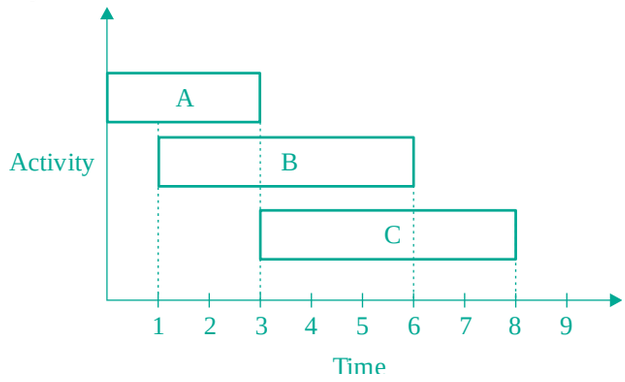
(C) Progressive costs of project

(D) Inventory costs

Sol. **(A)**

Gantt charts are mainly used to allocate resources to activities.

The resources allocated to activities include staff, hardware, and software. Gantt charts are useful for resource planning. A Gantt chart is a special type of bar chart where each bar represents an activity. The bars are drawn along a timeline. The length of each bar is proportional to the duration of time planned for the corresponding activity.



Hence, the correct option is (A).

ESE 2003

1.2 A serious limitation of inter dependences between various activities is generally observed in

(A) Bar charts

(B) Milestone charts

(C) Network analysis

(D) Job layouts

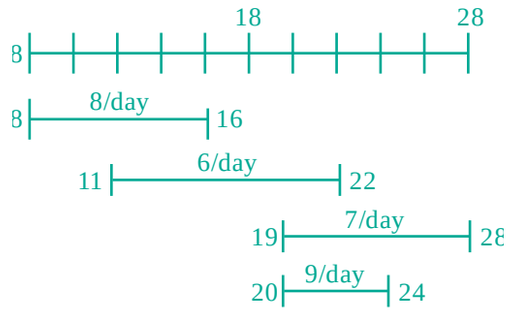
Sol. **(A)**

In bar charts inter dependences between various activities is not shown.

Hence, the correct option is (A).

ESE 2004

1.3 A bar chart of four activities indicating their scheduled start and finish "end-of-day" values and the resource requirement per day are given above. What will be the maximum and the minimum resource need on any of the days?



(A) 22, 6 (B) 21, 6 (C) 21, 6 (D) 20, 8

Sol. **(A)**

Minimum number of resources are needed on 18^{th} day i.e. 6 Nos.

Maximum number of resource are needed on 20^{th} day.

i.e. $22(6+7+9)$ Nos.

Hence, the correct option is (A).

ESE 2005

1.4 Consider the following statements :

The salient features of a bar chart over network are that :

1. It is simple to draw and easy to understand
2. It is unable to depict interdependence of activities
3. It is clearly distinguishes between critical and non-critical activities
4. It is not possible to crash activities to get optimum and minimum duration of the project

Which of the following statements given above are correct?

(A) 1, 2, 3 and 4 (B) 2 and 3 (C) 1, 2 and 4 (D) 1, 3 and 4

Sol. **(C)**

Silent features about bar chart :

1. Simple to draw and easy to understand
2. No trained/skill personnel required to draw bar chart.
3. Progress achieved at site can be expressed in terms of percentage.
4. It does not show interdependences among activities
5. It does not depicts critical and non critical activities.
6. It does not enables crashing i.e. cost optimization.

Hence, the correct option is (C).

1.5 Match **List-I** (Diagram Based Nomenclature) with **List-II** (Information Capability) and select the correct answer using the code given below the Lists :

List I

A. Work-breakdown structure

B. Bar chart

C. Linked bar chart

D. Time computations on network

List II

1. Target dates for interface events can be stipulated
2. Can be hierarchical
3. Can include information on cost distribution over time
4. Best suited for monitoring on network including that for costs

Codes :

	A	**B**	**C**	**D**
(A)	4	3	2	1
(B)	2	1	4	3
(C)	4	1	2	3
(D)	2	3	4	1

Sol. **(D)**

Work break down structure is hierarchical, in nature from top to bottom. Bar charts can be used to determine project cost over time.

As in linked bar chart interdependencies of all the activities is shown it can be used for monitoring of project including cost.

Time computations on network helps in calculation of interface events. Interface events are events common to two different project in a multi project network diagram.

Hence, the correct option is (D).

1.6 What is the significant purpose of monitoring a project throughout its implementation phase?

(A) To fix responsibility for delays

(B) To rerail the project with control over cost over-run

(C) To rerail the project with minimum time over-run

(D) To rerail the project with optimal time and cost over-run

Sol. **(A)**

Monitoring is related to identify deviations and to fix responsibility of deviations. Controlling is related to take corrective action for rerailing the project with optimum time and cost over-run.

Hence, the correct option is (A).

2 Fundamental of Network

ESE 1998

2.1 The network rules are common to all activity-on-arrow networking systems. The use of computers for making computations may impose certain rules. Which of the following basic rules of network logic are correct?

1. Before an activity may begin, all the activities preceding its must be complete.
2. Any two events may be directly connected by no more than one activity.
3. Event numbers must not be duplicated in a network.

Select the correct answer using the codes given below

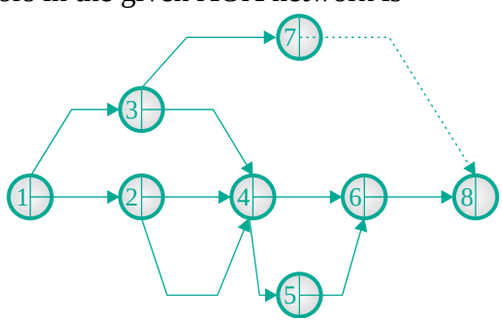
Codes :

(A) 1 and 2 (B) 2 and 3 (C) 1 and 3 (D) 1, 2 and 3

Sol. **(D)**

ESE 2000

2.2 The total number of errors in the given AOA network is



(A) 1 (B) 2 (C) 3 (D) 4

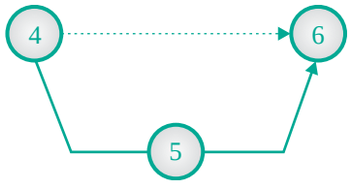
Sol. **(C)**

There are three error in the network.

1st :

One of this arrow shall be deleted.

2nd :



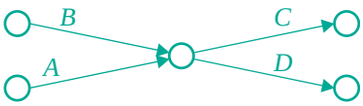
Dummy 4-6 is not required because it is a redundant dummy I.

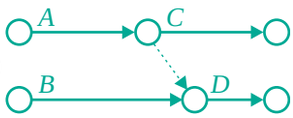
3rd : Dummy 7-8 is not required because it is only dummy comming out from node 7 and also it is only dummy entring node 8, hence it can be eliminated. Technically speaking there is no need of this dummy.

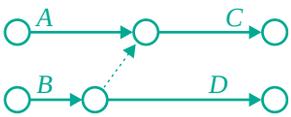
Hence, the correct option is (C).

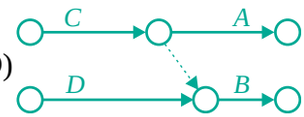
ESE 2001

2.3 Activity '*C*' follows activity '*A*' and activity '*D*' follows activities 'A' and B. The correct network for the projects is

(A)


(B)


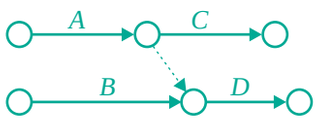
(C)


(D)


Sol. **(B)**

1st Step :

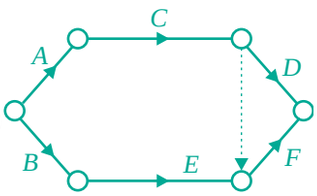
2nd step :

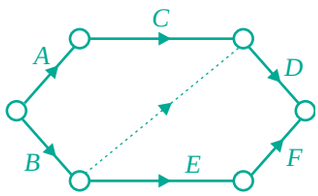


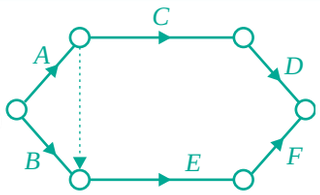
Hence, the correct option is (B).

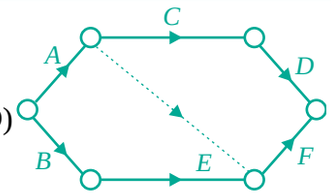
ESE 2006

2.4 Activities A and B can be started independently. Activity C follows activity A, and activity D follows activities B and C. Activity E follows activity B and precedes activity F. The activities D and F merge at the objective event. Which one of the following is the correct network of the project ?

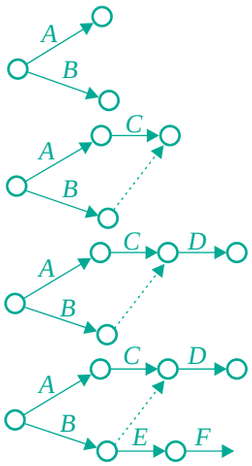
(A)


(B)


(C)


(D)


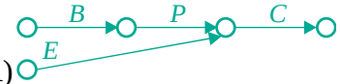
Sol. **(B)**

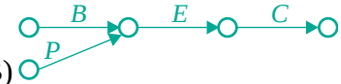


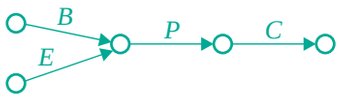
Hence, the correct option is (B).

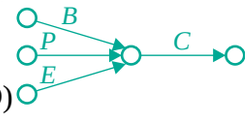
2.5 Consider the following tasks:

1. Placing of reinforcement (P) for roof slab cannot start before bending of reinforcement (B) and erection of frame work (E).
2. As soon as placing of reinforcement is finished, concreting (C) will follow. The correct activity on arrow diagram representing for the above tasks is :

(A)


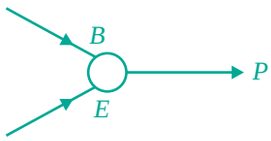
(B)


(C)


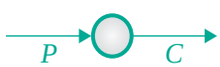
(D)


Sol. **(C)**

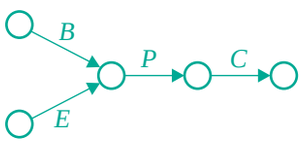
We observe that task P can not begin until both B and E are complete i.e.



Also, task C follows P i.e.



Therefore correct AOA representation will be :



Note : It is a partial Network diagram

Hence, the correct option is (C).

ESE 2010

2.6 **Assertion (A) :** A 'dummy' job is assigned zero' time to perform.

Reason (R) : It is used mainly to specify precedence relationship.

(A) Both Assertion and Reason are true and Reason is correct explanation of Assertion

(B) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion

(C) Assertion is true but Reason is false

(D) Assertion is false but Reason is true

Sol. **(A)**

A dummy activity is a type of activity in the network which neither consumes any time nor any resource. It is mainly used in the network to establish relationship between preceeding and succeeding activity.

Hence, the correct option is (A).

ESE 2014

2.7 In an Activity-on-Arrow network, which of the following rules of network logic are mandatory?

1. Any two events can be directly connected by not more than one activity.
2. Event numbers should not be duplicated in a network.
3. Before an activity may begin, all the activities preceding it must be completed.

Select the correct answer using the code given below.

(A) 1 and 2 only (B) 2 and 3 only (C) 1 and 3 only (D) 1, 2 and 3

Sol. **(D)**

2.8 **Statement (I) :** A dummy job takes zero time to perform.

Statement (II) : It is used solely to illustrate precedence relationship.

(A) Both Statement I and Statement II are true and Statement II is correct explanation of Statement I

(B) Both Statement I and Statement II are true but Statement II is not a correct explanation of Statement II

(C) Statement I is true but Statement II is false

(D) Statement I is false but Statement II is true

Sol. **(A)**

In most projects many activities can be performed concurrently or simultaneously. It is possible that two activities could be drawn by the same beginning and end events. In situation where two or more activities can be performed concurrently, the concept of dummy activity is introduced to resolve this problem. Therefore there will be only one activity between two points.

As a result of using dummy activity, other activities can be identified by unique end events. Dummy activities consume no time or resources. By convention, dummy activities are represented by a dashed arrow on the project network.

3 Programme Evaluation Review Technique (PERT)

ESE 1995

3.1 Consider the following features/factors:

1. Projects are of the non-repetitive type
2. Time required need not be known
3. Time required is known precisely
4. Events have been established for planning
5. Emphasis is given to activities of project.

PERT is preferred for planning because of

(A) 1, 2 and 4 (B) 3, 4 and 5 (C) 1, 3 and 4 (D) 1, 2 and 5

Sol. **(A)**

Silent points about PERT analysis :

(i) Uses Probabilistic approach which absorbs uncertainties in estimation of time.

(ii) It is used for projects where there is insufficient or no background information i.e. of non-repetitive type eg. R & D type of projects.

(iii) As there is not much information available about the activities hence events are established for the planning purpose and emphasis is given to the events of the projects.

Hence, the correct option is (A).

3.2 Given that : t = the duration of various jobs, t_m = mean time of different durations and n = number of observations.

The standard deviation is given by

(A) $\frac{\Sigma t}{n}$ (B) $t - t_m$ (C) $\frac{\Sigma (t - t_m)^2}{n}$ (D) $\sqrt{\frac{\Sigma (t - t_m)^2}{n}}$

Sol. **(D)**

We know that, $\sigma = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n}}$

Note that we use n in denominator when sample space is greater than or equal to 30, we use (n-1) when sample space is less than 30.

$\therefore$ $\sigma = \sqrt{\frac{\Sigma (t - t_m)^2}{n}}$

Hence, the correct option is (D).

3.3 For a given activity, the optimistic time, pessimistic time and the most probable estimates are 5, 17 and 8 days respectively. The expected time is

(A) 8 days (B) 9 days (C) 10 days (D) 15 days

Sol. **(B)**

We know that, $t_e = \dfrac{t_0 + 4t_m + t_p}{6} = \dfrac{5+4\times8+17}{6} = 9\,\text{days}$

Hence, the correct option is (B).

ESE 1997

3.4 The optimistic, most likely, and pessimistic estimates of time for an activity are 4 days, 11 days and 12 days respectively. The expected completion time of this activity is

(A) 8 days (B) 9 days (C) 10 days (D) 11 days

Sol. **(C)**

We know that, $t_e = \dfrac{t_0 + 4t_m + t_p}{6} = \dfrac{4+4\times11+12}{6} = 10\,\text{days}$

Hence, the correct option is (C).

3.5 The time estimates obtained from four contractors P, Q, R and S for executing a particular job are as under :

Contractor	Optimistic time t_0	Most likely time t_1	Pessimistic time t_p
P	5	10	13
Q	6	9	12
R	5	10	14
S	4	10	13

Which one of these contractor is more certain about completing the job in time?

(A) P (B) Q (C) R (D) S

Sol. **(B)**

Uncertainty and certainty of any activity or any project is determined by its variance. More is the variance, more is the uncertainty. Less is the variance less is uncertainty.

We know that, variance $= \left(\dfrac{t_p - t_0}{6}\right)^2$

t_p = Pessimistic time and t_0 = Optimistic time

Contractor	σ^2
P	1.78
Q	1
R	2.25
S	1.25

4 Critical Path Method (CPM)

ESE 1995

4.1 Match **List – I (Description of activity floats)** with **List – II (Names of the floats)** and select the correct answer using the codes given below the lists :

List I		List II	
A.	Earliest start time of its successor activity minus earliest finish time of activity in question	1.	Total
B.	Time available for an activity performance minus the duration of the activity	2.	Free
C.	Excess of minimum available time over the required activity duration	3.	Interfering
D.	Difference between total float and free float of an activity	4.	Independent

Codes :

	A	**B**	**C**	**D**
(A)	1	2	3	4
(B)	1	2	4	3
(C)	2	1	3	4
(D)	2	1	4	3

Sol. **(D)**

Total Float : It is the maximum available time by which an activity can be delayed without affecting the project completion time i.e., maximum available time for performance of activity minus activity duration.

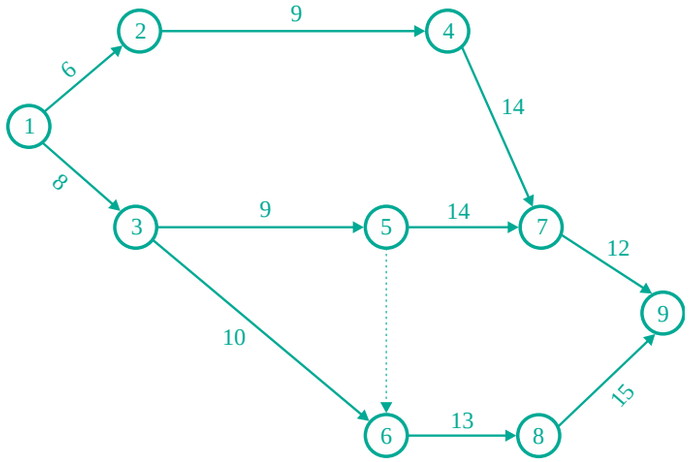
Free Float : It is the amount of time by which an activity can be delayed without affecting the earliest start time of succeeding activity.

Independent Float : It is amount of time by which an activity can be delayed when all the preceding activities are completed as late as possible and all succeeding activities are started as early as possible i.e. it is excess of minimum available time over the required activity duration.

Interfering Float : It is defined as difference of total float and free float which is also equal to slack of head event.

Hence, the correct option is (D).

4.2 The flow net of activities of a project is given in the following figure. The duration of activities are indicated along the arrows.

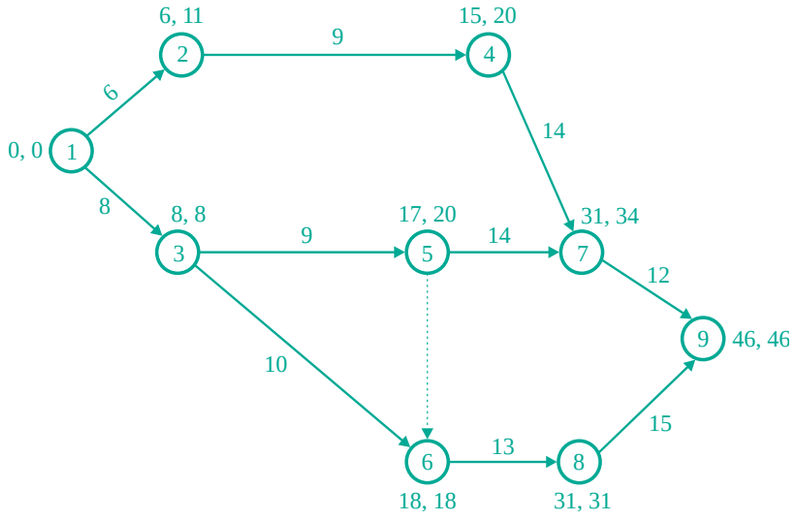


The critical path of the activities is along

(A) 1-2-4-7-9 (B) 1-3-5-7-9 (C) 1-3-6-8-9 (D) 1-3-5-6-8-9

Sol. **(C)**

We know that critical path is the longest duration path time wise in a network.



It is observed that 1-3-6-8-9 is the longest duration path therefore it will be critical path.

Hence, the correct option is (C).

4.3 Match **List – I (Item)** with **List – II (Characteristic)** and select the correct answer using the codes given below the lists :

List - I		List - II	
A.	Activity	1.	Resourceless element
B.	Event	2.	Resource consuming element
C.	Dummy	3.	Spare time
D.	Float	4.	Instantaneous stage

Codes :	A	B	C	D
(A)	1	3	4	2
(B)	2	1	4	3
(C)	2	4	1	3
(D)	3	4	1	2

Sol. **(C)**

Activity : It is a resource consuming element of a project.

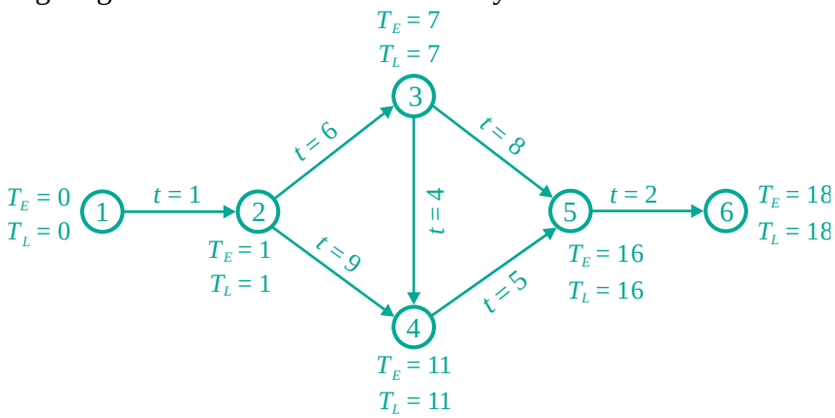
Event : It is an instant of time or state at which some specified milestone is achieved in the project.

Dummy : It is a special type of activity which does not consumes any resource.

Float : It is the time by which starting or finishing of an activity can be delayed without affecting the project completion time.

Hence, the correct option is (C).

4.4 The following diagram shows the details necessary for the CPM network analysis :



The critical path will be

(A) 1-2-3-5-6 (B) 1-2-3-4-5-6 (C) 1-2-4-5-6 (D) 1-2-4-3-5-6

Sol. **(B)**

We know that critical path is the longest path time wise in any network.

(i) 1-2-3-5-6 $\Rightarrow$ 17 days (ii) 1-2-3-4-5-6 $\Rightarrow$ 18days

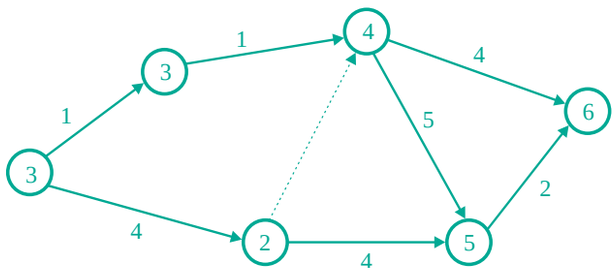
(iii) 1-2-4-5-6 $\Rightarrow$ 17 days (iv) 1-2-4-3-5-6 $\Rightarrow$ Not a valid option

Thus, critical path is 1-2-3-4-5-6.

Hence, the correct option is (B).

ESE 1997

4.5



5 Crashing

ESE 1995

5.1 Three-activities implementable in parallel, have the following time-cost relationship for direct cost component in each

Activity A : 10 days-800 units; 9 days-900 units; 8 days-1000 units

Activity B : 11 days-1200 units; 10 days-1350 units; 9 days-1500 units

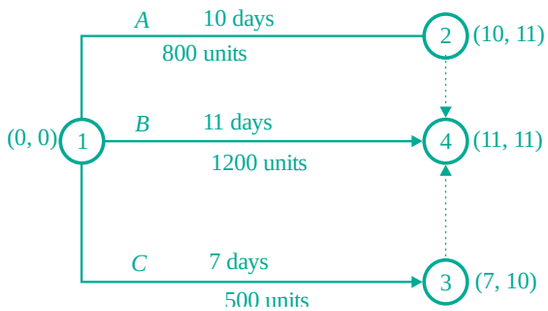
Activity C : 7 days-500 units; 6 days-700 units; 5 days-900 units

The feasible range of total direct cost component for the three activities together is

(A) 2500 to 3400 units (B) 2650 to 3200 units (C) 2500 to 2900 units (D) 2600 to 3100 units

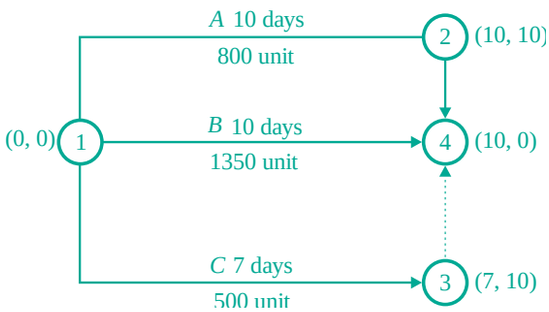
Sol. **(C)**

As three activities are implemented in parallel the network diagram will be as below :



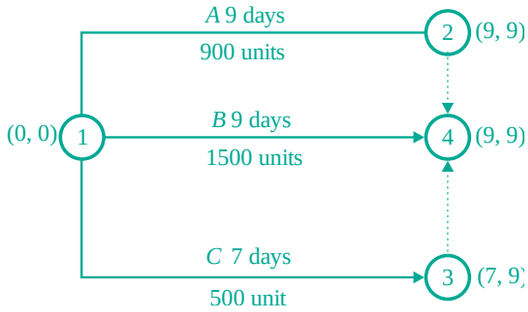
Total direct cost = 800 + 1200 + 500 = 2500 unit

Step I : Crashing activity B by 1 day as it is critical activity.



Total direct cost = 800 + 1350 + 500 = 2650 units

Step II : Crashing activity A & B by 1 day.



Total Direct cost = 900 + 15000 + 500 = 2900

∴ Feasible range is 2500 - 2900 units.

Hence, the correct option is (C).

ESE 1998

5.2 Consider the following statements :

Crashing a project in terms of its duration would result in

1. An increase in the indirect cost.
2. A decrease in the indirect cost.
3. A decrease in the direct cost.
4. An increase in the direct cost.

Of these statements

(A) 1 & 4 are correct (B) 2 & 3 are correct (C) 1 & 3 are correct (D) 2 & 4 are correct

Sol. (D)

Indirect cost of a project are those expenses which can not be associated or assigned to any individual activity of the project eg., establishment charges, insurance charges etc.

Direct cost are those expenses which are directly chargeable and can be identified by activities eg., cost of material, machine, labour etc.

During crashing of an activity, the duration of activity is reduced due to which :

(1) Indirect cost decreases (2) Direct cost increases

Hence, the correct option is (D).

5.3 In the time-cost optimization, using CPM method for network analysis, the crashing of the activities along the critical path is done starting with the activity having

(A) Longest duration (B) Highest cost slope (C) Least cost slope (D) Shortest duration

Sol. (C)

Crashing is started by crashing the activity along the critical path having least cost slope.

Hence, the correct option is (C).

5.4 Activity P is followed by Activity Q which in turn, is followed by Activity R. The direct cost of these activities in relation to the choice of feasible durations table is given below :

	Activity 'P'			Activity 'Q'			Activity 'R'		
Duration in days	7	6	5	8	7	6	9	8	7
Direct cost Rs. '000	12	14	17	20	23	27	40	42	45

For all the three activities taken together; the minimum possible direct cost for a total duration of 21 days will be

(A) Rs. 81,000 (B) Rs. 79,000 (C) Rs. 78,000 (D) Rs. 77,000

Sol. **(D)**

If project duration is 7+8+9 = 24 days then direct cost is

D.C = 12000 + 20000 + 40000 = 72000

If Activity P is crashed by 1 day then project duration = 23 days and D.C = 72000 + 2000 = 74000

If Activity P is again crashed by 1 day then project duration = 22 days and D.C = 74000 + 1000 = 75000

If Activity R is crashed by 1 day then project duration = 21 days then D.C = 7500 + 2000 = 77000.

Hence, the correct option is (D).

ESE 2000

5.5 **Assertion (A) :** Project -time cost schedules (inclusive of indirect costs) always show decreasing overall costs for decreasing overall project duration (so long as such compression is feasible).

Reason (R) : Generally, the incremental rate increases or consumption of a resource increases.

(A) Both Assertion and Reason are true and Reason is correct explanation of Assertion

(B) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion

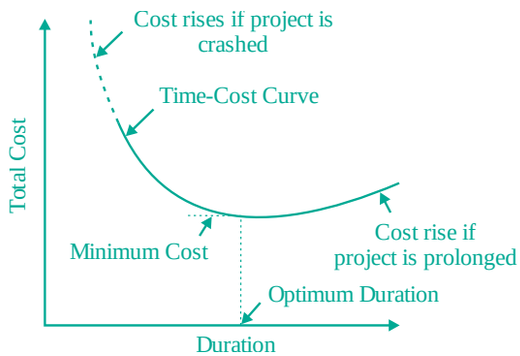
(C) Assertion is true but Reason is false

(D) Assertion is false but Reason is true

Sol. **(D)**

Total project cost v/s time curve decreases till the optimum project duration. Optimum project duration is that project duration at which project cost is minimum.

If project is prolonged above or shortened below the optimum project duration the total project cost will increase



Hence, the correct option is (D).

ESE 2001

5.6 In the time-cost analysis, the cost slope is defined as

(A) $\frac{\text{Crash cost} - \text{Normal cost}}{\text{Crash time} - \text{Normal time}}$ (B) $\frac{\text{Crash time} - \text{Normal time}}{\text{Crash cost} - \text{Normal cost}}$

(C) $\frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}}$ (D) $\frac{\text{Normal cost} - \text{Crash cost}}{\text{Normal time} - \text{Crash time}}$

6 Updating & Resources Allocation

ESE 1995

6.1 In resource levelling

(A) Total duration of project is reduced (B) Total duration of project is increased

(C) Uniform demand of resources is achieved (D) Cost of project is controlled

Sol. **(B)**

In the resource levelling process activities are rescheduled such that maximum demand of resources requirement does not exceed the limit of availability of resources. During this process at first re-arrangement of activities having floats is done. Even if by doing so, resource requirement is more than availability of resources, then duration of some activities is increased such that resource requirement of these activities is reduced. Hence project duration might get increased during the process of resource levelling.

Hence, the correct option is (B).

6.2 The following table contains data on four activities, A, B, C and D :

Activity	Starts at week number	Ends with week number	Resources needed per week
A	9th	16th	6
B	11th	20th	4
C	15th	22nd	3
D	13th	24th	7

The maximum total resource load in any week will be

(A) 20 (B) 17 (C) 16 (D) 14

Sol. **(A)**

The 15^{th}-16^{th} week demands most resources, because four activities A, B, C, D will run in parallel in that week.

$\therefore$ Resource demand = 6 + 4 + 3 + 7 = 20

Week	Resources for activity				Total
	A	B	C	D	
9	6	0	0	0	6
10	6	0	0	0	6

11	6	4	0	0	10
12	6	4	0	0	10
13	6	4	0	7	17
14	6	4	0	7	17
15	6	4	3	7	20
16	6	4	3	7	20
17	0	4	3	7	14
18	0	4	3	7	14
19	0	4	3	7	14
20	0	4	3	7	14
21	0	0	3	7	10
22	0	0	3	7	10
23	0	0	0	7	7
24	0	0	0	7	7

Hence, the correct option is (A).

ESE 1997

6.3 Consider the following statements :

Resource levelling means

1. Economical utilization of resources.
2. Gradual increase in resources.
3. Adjustment of resources to have the least variations.
4. Complete revamping of resources to suit the requirements.
5. Validating network depending on resource constraints.

Of these statements.

(A) 1 and 2 are correct
(B) 2, 3 and 4 are correct
(C) 3 and 5 are correct
(D) 1, 2, 3, 4 and 5 are correct

Sol. **(C)**

The main principal of resource levelling is that maximum demand of resource requirement shall not exceed the limit of availability of resources.

To satisfy this conditions activities are rescheduled such that peak demand is reduced to below or equal to the resources constraint value and parallel resources are adjusted such that there is a least variation in their demand.

Hence, the correct option is (C).

ESE 1998

6.4 Which of the following are the possible changes during the updating of the project network?

1. Change in the duration of an activity.
2. Addition or deletion of an activity.
3. Change in the logical relationships among the activities.

Select the correct answer using the codes given below :

Codes :

(A) 1, 2 and 3 (B) 1 and 2 (C) 2 and 3 (D) 1 and 3

Sol. **(A)**

Important points about updating :

(i) On any major change in duration of activity, updating is mandatory.

(ii) For critical activities updating is mandatory.

(iii) Critical path may change during updating.

(iv) During updating some activities are added or delated and logical relationship among activities is also changed.

Hence, the correct option is (A).

ESE 1999

6.5 **Assertion (A) :** In resource levelling, the project completion time is not extended even though there is no constraint in the availability of resources.

Reason (R) : There is generally a constraint against exceeding the project duration time.

(A) Both Assertion and Reason are true and Reason is correct explanation of Assertion

(B) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion

(C) Assertion is true but Reason is false

(D) Assertion is false but Reason is true

Sol. **(D)**

In resource levelling, there is a constraint on availability of resources and also project completion time may increase.

Hence, the correct option is (D).

ESE 2000

6.6 Five activities are scheduled between time 3 days and time 14 days in a bar chart. Resource loading per day for these activities, along with their durations are read on the bar chart grid are:

Activity	**A**	**B**	**C**	**D**	**E**
Duration	3-8	4-12	10-14	7-11	11-14
Resource loading per day	5	4	8	3	2

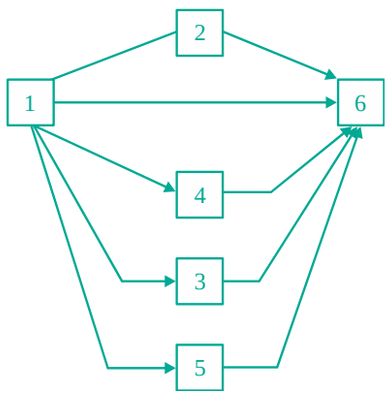
Match **List I (Resource loading per day)** with **List II (Day number)** derive from above data and select the correct answer

List - I		**List-II**	
A.	16	1.	12^{th}
B.	15	2.	14^{th}
C.	14	3.	None
D.	12	4.	11^{th}
		5.	8^{th}

7 A-O-N Diagram

ESE 2003

7.1 A-O-N network is suggested as shown in figure. The number of errors/incompatibilities in this network is



(A) 1 (B) 2 (C) 3 (D) 4

Sol. **(C)**

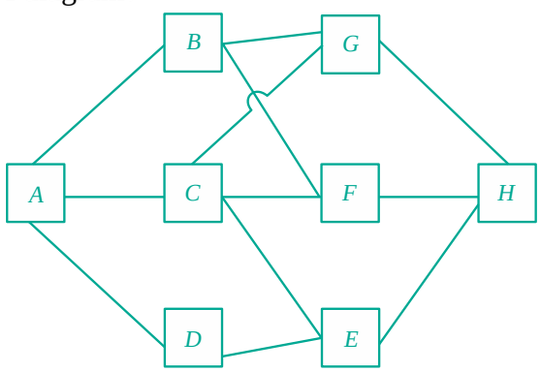
There are three errors in the given A-O-N network diagram.

$1 \rightarrow 6$, $1 \rightarrow 4$ and $3 \rightarrow 6$ are redundant

Hence, the correct option is (C).

ESE 2004

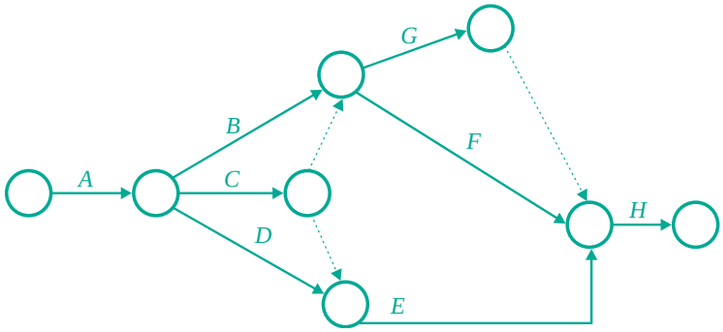
7.2 Consider the AON diagram. What is the minimum number of dummy arrows required for conservation into AOA diagram?



(A) 3 (B) 4 (C) 5 (D) 6

Sol. **(A)**

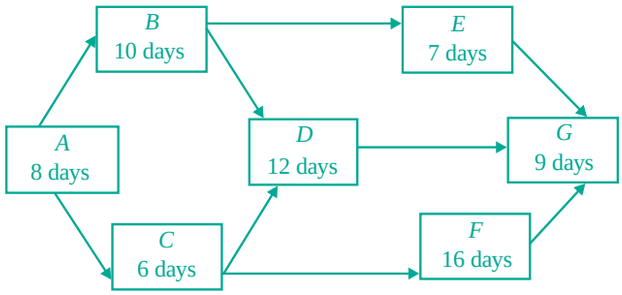
A-O-A diagram for A-O-N diagram is as below.



Hence, the correct option is (A).

ESE 2006

7.3 A small project, consists of seven activities in the activity-on-node diagram as shown in the figure above. The duration of these activities, in days and the predecessor relationships are shown. What is the total project duration of the project?



(A) 39 days (B) 35 days (C) 34 days (D) 41 days

Sol. **(A)**

Total project duration is 39 days along paths.

(i) A-B-D-G = 39 days (ii) A-C-F-G = 39 days

Hence, the correct option is (A).

ESE 2008

7.4 **Assertion (A) :** Linked bar chart cannot be developed from an AON network as easily as from an AOA network.

Reason (R) : AON networks do not incorporate information corresponding to dummy arrows of AOA networks.

(A) Both Assertion and Reason are true and Reason is correct explanation of Assertion

(B) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion

(C) Assertion is true but Reason is false

(D) Assertion is false but Reason is true

8 Engineering Economy

ESE 1995

8.1 The original cost of an equipment is Rs. 10,000. Its salvage value at the end of its total useful life of five years is Rs. 1,000. Its book value at the end of two years of its useful life (as per straight line method of evaluation of depreciation) will be

(A) Rs. 8,800 (B) Rs. 7,600 (C) Rs. 6,400 (D) Rs. 5,000

Sol. **(C)**

From straight line method of depreciation

Depreciation, $D = \frac{C_i - C_s}{n} = \frac{10000 - 1000}{5} = 1800$

Book value, $B_m = C_i - mD$

$B_2 = 10000 - 2 \times 1800 = 6400$

Hence, the correct option is (C).

ESE 1996

8.2 Cost-benefit studies are essential to

(A) Assess the total cost of the work

(B) Ascertain the relevant escalation in prices

(C) Monitor the expenditure

(D) Evaluate the viability and worth whiteness of taking up the project

Sol. **(D)**

Cost benefit studies is a systematic process for calculating and comparing benefits and cost of a project. It involves comparing total expected cost against total expected benefits.

Purpose :

(1) To find out if it is a sound investment/Decision (Viable/worthwhile)

(2) It provides basis for comparing of projects in terms of cost, benefits and etc.

Hence, the correct option is (D).

ESE 1998

8.3 Sensitivity analysis is a study of

(A) Comparison of profit and loss

(B) Comparison of assets and liabilities

(C) Change in output due to change in input

(D) Economics of costs and benefits of the project

Sol. **(C)**

Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system can be apportioned to different source of uncertainty in its inputs.

Hence, the correct option is (C).

8.4 With the usual notations, sinking fund factor is given by

(A) $(1+i)^n$ (B) $\dfrac{i}{\left((1+i)^n-1\right)}$ (C) $\dfrac{1}{(1+i)^n}$ (D) $\dfrac{(1+i)^n}{\left((1+i)^n-1\right)}$

Sol. **(B)**

Sinking fund is that amount which has to be set aside at the fixed intervals of time out of gross income so that at the end of the useful life of the equipment, the fund should accumulated equal to the initial cost of the equipment,

$$\text{S.F.F} = \frac{i}{(1+i)^n - 1}$$

Hence, the correct option is (B).

ESE 1999

8.5 Capital recovery factor at 15% p.a. discrete compounding for 4 years is 0.35. Rs. 10,000 deposited now at 15% discrete compounding will yield an amount 'X' at the end of each 4-years period in perpetuity. The value of 'X' is

(A) Rs. 7,500 (B) Rs. 6,666 (C) Rs. 6,000 (D) Rs. 5,000

Sol. **(A)**

Given : i = 15% ; n = 4 ; CRF = 0.35

$$X = \frac{P \times i}{\text{S.F.F}}$$

$$\text{S.F.F} = \text{C.R.F} - i = 0.20$$

Capitalized amount, $X = \dfrac{10000 \times 0.15}{0.20} = 7500$

Hence, the correct option is (A).

8.6 A machine costs Rs. 16,000. By constant rate of declining balance method of depreciation, its salvage value after an expected life of 3 years is Rs. 2,000. The rate of depreciation is

(A) 0.25 (B) 0.30 (C) 0.40 (D) 0.50

9 Construction Equipment

ESE 1996

9.1 Match **List – I** with **List – II**

List I		List II	
A.	Derrick	1.	Stone masonry work
B.	Claw hammer	2.	Wood work
C.	Chain-Lewis	3.	Steel work
D.	Drop-hammer	4.	Concrete compaction
		5.	Pile foundation

Codes :

	A	B	C	D
(A)	1	3	5	4
(B)	2	3	4	5
(C)	3	1	5	2
(D)	3	2	1	5

Sol. **(D)**

Derrick crane is a hoisting equipment which is capable of providing 3-D movement of weight eg : lifting of shuttering, reinforcement, steel work etc.

Chain lewis is used for lifting loads upto 50 tonnes eg. stones used for stone masonry. It is a simple and economical system which consists of hand chain and a load chain supported over a pulley.

Drop hammer is a heavy metal weight that is lifted by a hoist line then released and allowed to fall on to the top of pile. These are suitable for driving piles in remote places which requires only few piles and for which the time of completion is not an important factor.

Hence, the correct option is (D).

9.2 The maximum rimpull in the first gear of a tractor while towing a load is 6300 kg. The tractor weighs 12 tonnes and is operating along a 2 per cent upgrade and the rolling resistance is 45 kg/tonne. Pull available for towing the load is

(A) 3425 kg (B) 5515 kg (C) 4350 kg (D) 2975 kg

Sol. **(B)**

Available pull = Maximum Rimpull– Rolling Resistance – Grade resistance

Rolling Resistance $= 12 \times 45 = 540$ kg

$\because$ Grade Resistance = 10 kg for 1% grade for 1 tonne

$\therefore$ Grade resistance $= 2 \times 10 \times 12 = 240$ kg

Available pull $= 6300 - 540 - 240 = 5520$ kg

Hence, the correct option is (B).

9.3 The tipping load of a crane refers to

(A) Lifted weight together with all attached handling tackle and hoist rope, with grounded attached outriggers

(B) Lifted weight together with all attached handling tackle but excluding hoist rope, with specifying the radius horizontally, with grounded outriggers

(C) Lifted weight alone, with specifying the radius for the lifted weight and also for the counter weight without grounding the outriggers

(D) Lifted weight alone, at specified horizontal radius without grounding the outriggers

Sol. **(A)**

Tipping load is the load that produces a toppling condition at a specified radius. Tipping load includes the weight of the item being lifted plus the weight of hoist rope, hooks, hook blocks, slings and any other items used in hoisting the load.

Hence, the correct option is (A).

ESE 1997

9.4 Grader is used mainly for

(A) Trimming and finishing

(B) Shaping and trimming

(C) Finishing and shaping

(D) Finishing, shaping and trimming

Sol. **(D)**

Grader is a equipment used for :

(1) Levelling

(2) Shaping

(3) Finishing

(4) Mixing gravel

(5) Making Windrows

(6) Trimming slopes

Hence, the correct option is (D).

9.5 Which one of the following is NOT an excavating and moving type of equipment?

(A) Bulldozer (B) Clam shell (C) Scraper (D) Dump truck

Sol. **(D)**

Excavating and moving types of equipments are Power Shovel, Hoe, Dragline, Clamshell, Bulldozer, Scraper, Trencher etc. Dump trucks are used for the purpose of hauling or earth moving equipments.

Hence, the correct option is (D).

10 Labour, Safety & Welfare, Land Acquisation

ESE 2010

10.1 On a particular construction project, the contractor on an average employed 100 workers with 50 hour per week. The project lasted for 35 weeks and during this period, 14 disabling injuries occurred. The injury-frequency rate is

(A) 6 (B) 7 (C) 8 (D) 9

Sol. **(C)**

Injury frequency rate is equal to number of disabling injuries per 1,00,000 man-hours.

$$\therefore \quad \text{Injury frequency rate} = \frac{14 \times 10^5}{100 \times 50 \times 35} = 8$$

Hence, the correct option is (C).

ESE 2017

10.2 Consider the following statements regarding quality control:

1. It refers to absolute conformity to specifications.
2. It may not vouch against overspending.
3. It may unknowingly resort to overdesign in the hope of risk minimization.
4. It is intended to reduce maintenance costs.

Which of the above statements are correct?

(A) 1 and 3 (B) 2 and 3 (C) 2 and 4 (D) 1 and 4

Sol. **(D)**

Quality control is meant for confirming the design specifications and reducing maintenance costs. Increase in sale is the main objective of quality control system. Quality control is an important technique in the hands of the management to maintain the quality of the product.

By undertaking effective inspection and control over production processes and operations, production costs are considerably reduced. Quality control further checks the production of inferior products and wastages thereby bringing down the cost of production considerably.

Quality control ensures maximum utilisation of available resources thereby minimising wastage and inefficiency of every kind. By producing better quality products and satisfying customer's needs, quality control raises the goodwill of the concern in the minds of people. A reputed concern can easily raise finances from the market.

10.3 **Statement (I) :** Hiring and firing is a poor substitute for proper selection and proper training of labourers.

Statement (II) : Bad training facilities for new employees cause them to be discharged during or at the end of the probationary period.

Sol. **(B)**

Hiring defined as the addition of workers to provide better service to the company and firing is defined as the reduction in number of workers for not providing service as desired by employer.

The primary rationale for an organization is that, they have the ability to fire an employee under probation at any time. But once, the probation is completed, an employee can only be fired for the cause.

A probation period can be completed successfully by giving the proper training and giving awareness about each and every filed in which company is working.

Hence, the correct option is (B).

ESE 2018

10.4 Consider the following statements regarding labour welfare :

1. Work prompted by mere sympathy and kindness may degenerate and may injure the worker's sense of self-respect
2. Rapid industrialization on a large scale poses problems in respect of labour and its welfare
3. Construction labour is still largely unorganized, and, hence, lacks in welfare measures

Which of the above statements are correct ?

(A) 1 and 2 only (B) 1 and 3 only (C) 1, 2 and 3 (D) 2 and 3 only

Sol. **(C)**

All statements are correct and self -explanatory.

Statement I : True

Kindness is defined as the quality of being friendly, generous, and considerate. Work prompted by mere sympathy and kindness may reduces the self-confidence or workers,

Statement II : True

Some Drawbacks of Rapid Industrializations are :

1. Industrialization contributes to negative environmental externalities, such as pollution, increased greenhouse gas emission, and global warming.
2. The separation of capital and labor creates a disparity in incomes between laborers and those who control capital resources.
3. Industrialization also contributes to the deterioration of health among workers, crimes, stress, and other societal problems.

Statement III : True

The construction labours lacks labour welfare schemes due to following features of unorganized sector:

1. No job security
2. No regular job.
3. There are laws in this sector but are not followed.

11 Miscellaneous

ESE 1995

11.1 'Functional organization' system of working was introduced by

(A) F.W. Taylor (B) Henry Gantt (C) M.R. Walker (D) J.E. Kelley

Sol. **(A)**

The concept of functional organization was suggested by F.W. Taylor who recommended the appointment of specialists at important positions.

Functional organization allows decision to be decentralized since issues are assigned to specialized persons or units, giving them the responsibility of implementing, equating, or controlling the given procedures or goals.

Hence, the correct option is (A).

ESE 1996

11.2 Consider the following statements :

A floating floor construction can

1. Efficiently absorb impact noise
2. Efficiently insulate against impact noise
3. Efficiently insulate against airborne noise.

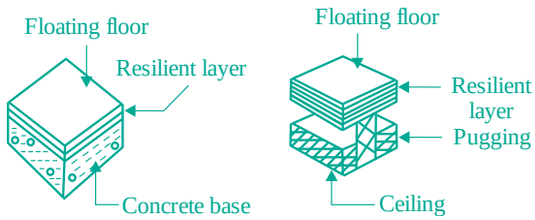
Of these statements

(A) 1, 2 and 3 are correct (B) 1 and 2 are correct

(C) 2 and 3 are correct (D) 1 and 3 are correct

Sol. **(C)**

Sound Insulation of floors :



Concrete Floor **Timber Floor**

Floating floor is used to resist impact sound and to some extent resists airborne sound. It is a floor used in sound insulating construction.

Hence, the correct option is (C).

11.3 Match **List – I (Indications of terms) with List – II (Terms)** and select the correct answer

List - I		List – II	
A.	Used for recording instructions given by the Executive Engineer site	1.	Co-ordination
B.	Used widely for civil engineering construction	2.	Unity of command
C.	One of the principles of organization	3.	Line organization
D.	One of the functions of management	4.	Site order book

Codes : **A B C D**

(A) 4 3 2 1

(B) 4 2 3 1

(C) 2 4 1 3

(D) 4 1 2 3

Sol. **(A)**

Site order book is a register maintained by the contractor which is used to record instruction given by client or executive engineer.

Line organization is the oldest and simplest form of organizations adopted in construction projects. Here, there is a clear line of authority and responsibilities between the superiors and subordinates is clearly fixed.

Principals of organizations are :

(a) Span of management (b) Unity of command

(c) Delegation of authority (d) Division of work and etc.

Functions of management are :

1. Forecasting 2. Planning 3. Organizing 4. Commanding

5. Co-ordinating 6. Controlling

Hence, the correct option is (A).

ESE 1997

11.4 Match **List – I (Type of work)** with **List – II (Type of contract most appropriate) and** select the correct answer using the codes given below the Lists.

List - I		List – II	
A.	Specified architectural work	1.	'Cost plus'
B.	House construction	2.	Lump sum
C.	Repainting of house	3.	Item rate
D.	Dewatering foundations	4.	Piece work

Codes : **A B C D**

(A) 3 2 1 4

(B) 2 3 4 1

(C) 2 3 1 4

(D) 3 2 4 1

Sol. **(D)**

Fixed-Price or lump-sum Contracts sets a fixed fee for the work. The contractor agrees to do the described and specified work for a fixed price.

Cost-Pius Contracts are used where the true nature or extent of work are unknown and where the risk factor is high.

In Item Rate Contract Instead of total amount or quantity of work in any item, the rate of the item is quoted by the contractor. The contractor agrees to carry out a unit quantity of a particular work for a particular sum of money.

Piece-work Contract is suited for small works like site-clearance, maintenance or repair works etc.

In this method, contractor agrees to execute a specific work for a specified rate without reference to the quantity of work involved or the time taken for completing the work.

Hence, the correct option is (D).

11.5 The profits and the associated probability of making the profits are given below in respect of four projects :

Project	Profit	Probability of making the profit
1	15%	0.5
2	10%	0.8
3	12%	0.7
4	11%	0.6

When the motive is maximization of expected profit, the correct order of preference of these projects would be

(A) 1, 3, 4, 2 (B) 2, 3, 4, 1 (C) 3, 2, 1, 4 (D) 3, 4, 2, 1

Sol. **(C)**

Expected profit = (Profit) × Probability of making the profit.

Project Order of preference	Expected profit
1. $0.5\times15\% = 7.5\%$	III
2. $0.8\times10\% = 8\%$	II
3. $0.7\times12\% = 8.4\%$	I
4. $0.6\times11\% = 6.6\%$	IV

Hence, the correct option is (C).

11.6 The issue rate of an item stocked in stores is

(A) Permanently fixed

(B) Fixed at the beginning of each year.

(C) A rate less than the market rate

(D) The rate revised during the year when there is an appreciable variation in the rates of the items.

Sol. **(D)**

Issue rate to the charged should not be less than the market rates.

Hence, the correct option is (D).

ESE 2026

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Paper-II (Civil Engineering)	3 hrs.	300
Total		500

B. Stage-II (Main/Stage-II) Examination :

Subject	Duration	Maximum Marks
Category - I Civil Engineering		
Paper-I (Civil Engineering)	3 hrs.	300
Paper-II (Civil Engineering)	3 hrs.	300
Total		600

Syllabus

Paper-I Syllabus :

Contents for syllabi of both the Papers together for Preliminary Examination/Stage-I (objective type Paper–II) and separately for Main/Stage-II Examination (Conventional type Paper-I and Paper – II).

1. **Building Materials :** Stone, Lime, Glass, Plastics, Steel, FRP, Ceramics, Aluminum, Fly Ash, Basic Admixtures, Timber, Bricks and Aggregates: Classification, properties and selection criteria;
   Cement : Types, Composition, Properties, Uses, Specifications and various Tests; Lime & Cement Mortars and Concrete: Properties and various Tests; Design of Concrete Mixes: Proportioning of aggregates and methods of mix design.
2. **Solid Mechanics :** Elastic constants, Stress, plane stress, Strains, plane strain, Mohr's circle of stress and strain, Elastic theories of failure, Principal Stresses, Bending, Shear and Torsion.
3. **Structural Analysis :** Basics of strength of materials, Types of stresses and strains, Bending moments and shear force, concept of bending and shear stresses; Analysis of determinate and indeterminate structures; Trusses, beams, plane frames; Rolling loads, Influence Lines, Unit load method & other methods; Free and Forced vibrations of single degree and multi degree freedom system; Suspended Cables; Concepts and use of Computer Aided Design.
4. **Design of Steel Structures :** Principles of Working Stress methods, Design of tension and compression members, Design of beams and beam column connections, built-up sections, Girders, Industrial roofs, Principles of Ultimate load design.
5. **Design of Concrete and Masonry Structures :** Limit state design for bending, shear, axial compression and combined forces; Design of beams, Slabs, Lintels, Foundations, Retaining walls, Tanks, Staircases; Principles of pre-stressed concrete design including materials and methods; Earthquake resistant design of structures; Design of Masonry Structure.
6. **Construction Practice, Planning and Management :** Construction - Planning, Equipment, Site investigation and Management including Estimation with latest project management tools and network analysis for different Types of works; Analysis of Rates of various types of works; Tendering Process and Contract Management, Quality Control, Productivity, Operation Cost; Land acquisition; Labour safety and welfare.

Paper-II Syllabus :

1. **Flow of Fluids, Hydraulic Machines and Hydro Power :**
   - **(a) Fluid Mechanics, Open Channel Flow, Pipe Flow :** Fluid properties; Dimensional Analysis and Modeling; Fluid dynamics including flow kinematics and measurements; Flow net; Viscosity, Boundary layer and control, Drag, Lift, Principles in open channel flow, Flow controls. Hydraulic jump; Surges; Pipe networks.
   - **(b) Hydraulic Machines and Hydro power :** Various pumps, Air vessels, Hydraulic turbines – types, classifications & performance parameters; Power house –classification and layout, storage, pondage, control of supply.

2. **Hydrology and Water Resources Engineering :** Hydrological cycle, Ground water hydrology, Well hydrology and related data analysis; Streams and their gauging; River morphology; Flood, drought and their management; Capacity of Reservoirs.

   Water Resources Engineering : Multipurpose uses of Water, River basins and their potential; Irrigation systems, water demand assessment; Resources - storages and their yields; Water logging, canal and drainage design, Gravity dams, falls, weirs, Energy dissipaters, barrage Distribution works, Cross drainage works and head-works and their design; Concepts in canal design, construction & maintenance; River training, measurement and analysis of rainfall.

3. **Environmental Engineering :**

   (a) Water Supply Engineering : Sources, Estimation, quality standards and testing of water and their treatment; Rural, Institutional and industrial water supply; Physical, chemical and biological characteristics and sources of water, Pollutants in water and its effects, Estimation of water demand; Drinking water Standards, Water Treatment Plants, Water distribution networks.

   (b) Waste Water Engineering : Planning & design of domestic waste water, sewage collection and disposal; Plumbing Systems. Components and layout of sewerage system; Planning & design of Domestic Waste-water disposal system; Sludge management including treatment, disposal and re-use of treated effluents; Industrial waste waters and Effluent Treatment Plants including institutional and industrial sewage management.

   (c) Solid Waste Management : Sources & classification of solid wastes along with planning & design of its management system; Disposal system, Beneficial aspects of wastes and Utilization by Civil Engineers.

   (d) Air, Noise pollution and Ecology : Concepts & general methodology.

4. **Geo-technical Engineering and Foundation Engineering :**

   (a) Geo-technical Engineering : Soil exploration - planning & methods, Properties of soil, classification, various tests and interrelationships; Permeability & Seepage, Compressibility, consolidation and Shearing resistance, Earth pressure theories and stress distribution in soil; Properties and uses of geo-synthetics.

   (b) Foundation Engineering : Types of foundations & selection criteria, bearing capacity, settlement analysis, design and testing of shallow & deep foundations; Slope stability analysis, Earthen embankments, Dams and Earth retaining structures: types, analysis and design, Principles of ground modifications.

5. **Surveying and Geology :**

   (a) Surveying : Classification of surveys, various methodologies, instruments & analysis of measurement of distances, elevation and directions; Field astronomy, Global Positioning System; Map preparation; Photogrammetry; Remote sensing concepts; Survey Layout for culverts, canals, bridges, road/railway alignment and buildings, Setting out of Curves.

   (b) Geology : Basic knowledge of Engineering geology & its application in projects.

6. Transportation Engineering :

Highways : Planning & construction methodology, Alignment and geometric design; Traffic Surveys and Controls; Principles of Flexible and Rigid pavements design.

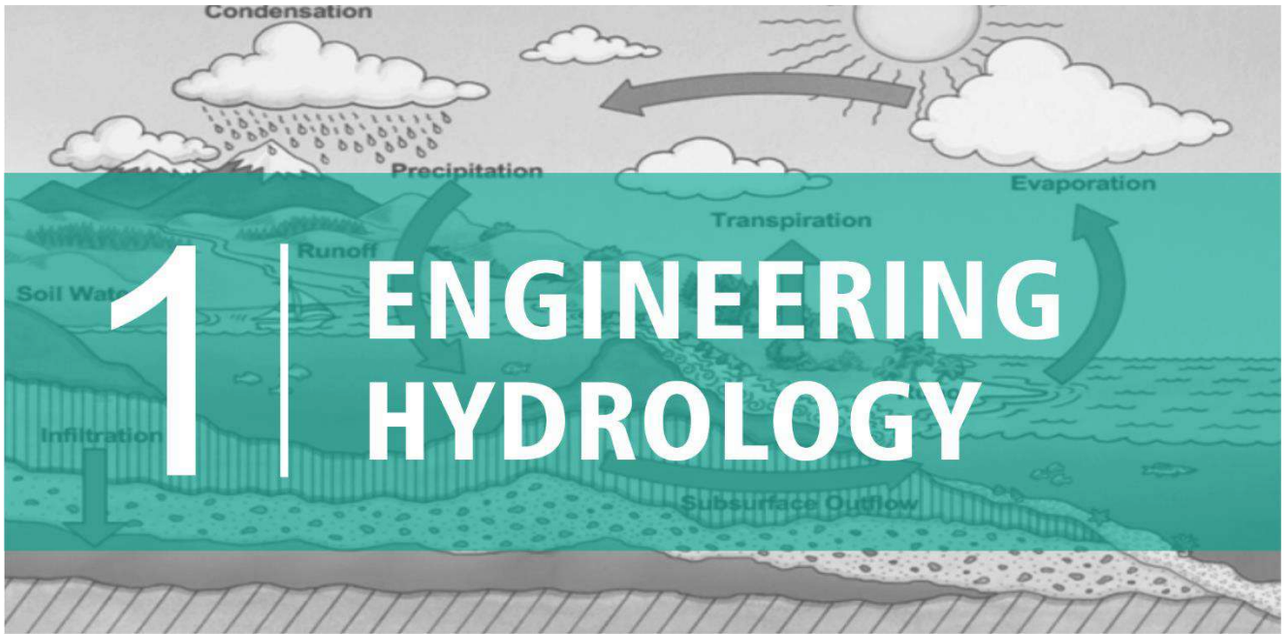
Tunneling : Alignment, methods of construction, disposal of muck, drainage, lighting and ventilation.

Railways Systems : Terminology, Planning, designs and maintenance practices; track modernization.

Harbours : Terminology, layouts and planning.

Airports : Layout, planning & design.

CONTENT



1 | ENGINEERING HYDROLOGY

Syllabus : Engineering Hydrology

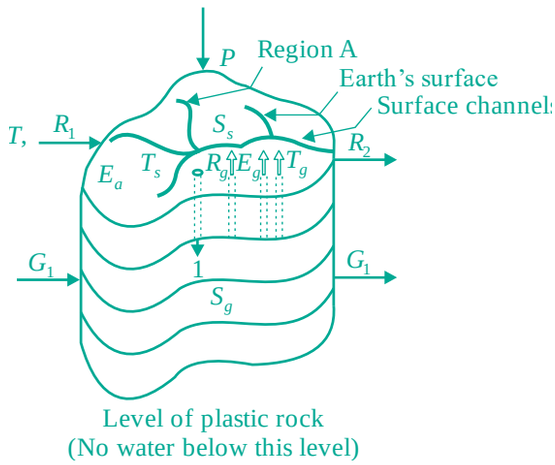
Hydrological cycle, precipitation and related data analysis, PMP, unit hydrographs and synthetic unit hydrographs; Evaporation and transpiration; Floods and their management, PMF; Streams and their gauging: River morphology; Routing of floods; Capacity of Reservoirs, Ground water hydrology.

Contents : Engineering Hydrology

1 Introduction

ESE 2002

1.1 Regional hydrological cycle is shown in the figure



The correct hydrologic budget equation is

(A) $P + R_1 - R_2 + R_g - E_s - T_s - I = \Delta S_s$

(B) $I + G_1 - G_2 + R_0 - E_s - T_g = \Delta S_g$

(C) $P - (R_2 - R_1) - (E_s + E_g) - (T_s + T_g) - (G_2 - G_1) = \Delta(S_s + S_g)$

(D) $P - R - G - E - T = \Delta S_s$

Sol. **(C)**

The Hydrologic budget equation is : $P - R - E - T - G = \Delta S$

Where, $P =$ Total precipitation, $R =$ Net runoff $= R_2 - R_1 =$ Surface runoff outflow – surface runoff, $E =$ Total evaporation, $T =$ Total transpiration, $G =$ Net ground water flow = Ground water inflow and $\Delta S =$ Total storage increase

$\therefore$ The equation becomes, $P - (R_2 - R_1) - (E_s + E_g) - (T_s + T_g) - (G_2 - G_1) = \Delta(S_s + S_g)$

Hence, the correct option is (C).

ESE 2007

1.2 The quantitative statement of the balance between water gains and losses in a certain basin during a specified period of time is known as which one of the following?

1. Water budget 2. Hydrologic budget 3. Ground budget

(A) 1 only (B) 2 only (C) 3 only (D) none of these

Sol. **(A)**

For a particular basin or catchment the equation showing the water gains and losses during a specified period of time is called water budget equation.

Hence, the correct option is (A).

ESE 2008

1.3 What is the chemical symbol for ice as per UNESCO terminology

(A) H_8O_4 (B) H_2O (C) H_6O_3 (D) H_4O_2

Sol. **(B)**

Chemical symbol of ice as per UNESCO is H_2O.

Hence, the correct option is (B).

ESE 2009

1.4 What is 'Hydrological Cycle'?

(A) Process involved in the transfer of moisture from sea to land

(B) Processes involved in the transfer of moisture from sea back to sea again

(C) Processes involved in the transfer of water from snowmelt in mountains to sea

(D) Processes involved in the transfer of moisture from sea to land and back to sea again

Sol. **(D)**

Hydrological cycle is the cycle in which water is transported from the oceans to the atmosphere as vapours, from the atmosphere to the land as precipitation and back from land to oceans as runoff.

Hence, the correct option is (D).

ESE 2012

1.5 Which of the following are pertinent to the realization of hydrological cycle?

1. Latitudinal difference in solar heating of the Earth's surface
2. Inclination of the Earth's axis
3. Uneven distribution of land and water
4. Coriolis effect

(A) 1, 2 and 3 only (B) 1,2 and 4 only (C) 2, 3 and 4 only (D) 1,2, 3 and 4

2 Measurement of Precipitation

ESE 1995

2.1 An accurate estimate of average rainfall in a particular catchment area can be obtained by :

(A) Arithmetic mean method
(B) Isohyetal method
(C) Normal ratio method
(D) THEISSEN polygon method

Sol. **(B)**

Average rainfall over a catchment area can be estimated using following methods :

1. **Arithmetic mean method :** In this method average rainfall is taken to be the mean of rainfall datas collected at various raingauge stations of the catchment area i.e., every rain gauge station is given equal weightage regardless of its location. This can be used when the rainfall is almost uniformly distributed over the whole catchment area which rarely occurs in nature. The method is fast but does not give accurate results.
2. **Theissen polygon method :** This method gives weightage to the various rainfall datas based on area close to the rain gauge station called theissen polygon areas. The method is fast when once the weights are known. But it does not take care of the variability in rainfall due to elevation difference, (i.e., topographical influence are not taken care of). New polygon is required to be drawn when, due to addition or deletion of raingauges to the network, weight of each station changes.
3. **Isohyetal method :** This is the most accurate method. It utilizes all relevant datas and properly interpret them. However the method is very slow and laborious.
4. Normal ratio method is used to estimate missing rainfall data.

Hence, the correct option is (B).

ESE 1996

2.2 The percentage standard error of precipitation averages is often expressed functionally or graphically in terms of (i) precipitating gauge network density expressed as area per gauge, and (ii) total area of catchment. The percentage standard error

(A) Increases with area per gauge as well as with total area
(B) Decreases with area per gauge as well as with total area
(C) Increases with area per gauge but decreases with total area
(D) Decreases with area per gauge but increases with total area

Sol. **(A)**

For accurate estimation of average precipitation, rainfall data available should be more. As number of raingauge stations increases, the accuracy in estimation of average precipitation also increases. Hence as area per gauge increases percentage standard error of precipitation averages will increase. Also with increase in total area of catchment percentage standard error of precipitation averages will increase. So correct option is (a). Note that rain gauge network density is expressed as area per gauge so when rain gauge network density increases percentage standard error of precipitation averages will increase as area per gauge will increase.

Hence, the correct option is (A).

2.3 If 'p' is the precipitation, 'a' is the area represented by a rain gauge, and 'n' is the number of rain gauge stations in a catchment area, then the weighted mean rainfall is

(A) $\frac{\sum ap^3}{\sum a^2}$ (B) $\frac{\sum ap}{n}$ (C) $\frac{\sum ap}{\sum a}$ (D) $\frac{\sum ap^5}{\sum a^3}$

Sol. **(C)**

If area represented by a rain gauge is 'a' and 'p' is the precipitation recorded by it and there are 'n' number of rain gauge stations in the catchment area then according to the theissen polygon method (also called Weighted area method) the weighted mean rainfall will be $\frac{\sum pa}{\sum a}$.

Hence, the correct option is (C).

2.4 Depth-Area-Duration curves of precipitation are drawn as

(A) Minimizing envelopes through the appropriate data points

(B) Maximizing envelopes through the appropriate data points

(C) Best fit mean curves through the appropriate data points

(D) Best fit mean straight lines through the appropriate data points

Sol. **(B)**

A brief description of the development of maximum Depth-Area-Duration curves for a region known as DAD analysis is given below-First the severe most rainstorms that have occurred in the region under question are considered. A depth-area curve of a given duration of the storm is prepared. Then, from the study of mass curve of rainfall, various durations and the maximum depth of rainfall in these durations are noted. The maximum Depth-Area curve for a given duration D is prepared by assuming the area distribution of rainfall for smaller duration to be similar to the total storm. The procedure is then repeated for different storms and the envelope curve of maximum Depth-Area for duration D is obtained. A similar procedure for various values of duration D results in a family of envelope curves of maximum depth vs area, with duration as third parameter. These curves are called DAD curves.

Hence, the correct option is (B).

3 Abstraction from Precipitation

ESE 2001

3.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	Anemometer	1.	Humidity
B.	Rain simulator	2.	Evapotranspiration
C.	Lysimeter	3.	Infiltration
D.	Hygrometer	4.	Wind speed

Codes :

	A	B	C	D
(A)	4	3	1	2
(B)	3	4	1	2
(C)	4	3	2	1
(D)	3	4	2	1

Sol. **(C)**

- Wind velocity is measured by Anemometer.
- Humidity is measured by Hygrometer (hygro refers to humidity).
- Evapotranspiration is measured using Lysimeter.
- Infiltration is measured using :

1. Flooding type infiltrometer
2. Rain simulator.

Hence, the correct option is (C).

3.2 A 3-hour storm on a small drainage basin produced rainfall intensities of 3.5 cm/hr, 4.2 cm/hr and 2.9 cm/hr in successive hours. If the surface runoff due to the storm is 3 cm, then the value of ϕ-index will be

(A) 2.212 cm/hr (B) 2.331 cm/hr (C) 2.412 cm/hr (D) 2.533 cm/hr

Sol. **(D)**

Total precipitation $= \sum$ intensity $\times$ Duration $= 3.5\times1+4.2\times1+2.9\times1 = 10.6\,\text{cm}$

Surface runoff = 3 cm

$\therefore$ Infiltration $= 10.6-3 = 7.6\,\text{cm}$

Assuming, t_e = time of rainfall excess = $3h$

Then, $$\phi = \frac{7.6}{3} = 2.533 \text{cm/hr}$$

In all the three successive hour, intensity of rainfall is more than ϕ index so our assumption of $t_e = 3h$ is correct.

Thus, ϕ index = 2.533 cm/hr

Hence, the correct option is (D).

ESE 2002

3.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	ϕ-index	1.	Used for measurement of evapotranspiration for given vegetation.
B.	Lysimeter	2.	Used for flow measurement.
C.	Dilution technique	3.	Average rainfall above which the rainfall volume is equal to the runoff volume.
D.	Snyder's equation	4.	Relates the basin lag to the basin characteristics

Codes :

	A	**B**	**C**	**D**
(A)	3	1	2	4
(B)	4	2	1	3
(C)	3	2	1	4
(D)	4	1	2	3

Sol. **(A)**

- ϕ-index is the average infiltration rate above which the total rainfall volume is equal to the runoff volume. It is the average infiltration rate during the period of rainfall excess.
- Following are the methods to measure the evapotranspiration (consumptive use) :
  1. Using Lysimeter
  2. Using field plots
  3. Using water budget equation
  4. Using empirical equations :
     - Penman's equation
     - Blanney-criddle's equation
- Dilution technique is used for flow measurement of small and turbulent streams.
- Snyder gave the synthetic unit hydrograph theory in which he related various hydrograph parameters with the basin characteristics.

Hence, the correct option is (A).

3.4 A 6-hour rainstorm with hourly intensities of 7, 18, 25, 17, 11 and 3 mm/hour produced a runoff of 39 mm. Then, the ϕ - index is

(A) 3 mm/hour (B) 7 mm/hour (C) 8 mm/hour (D) 10 mm/hour

Sol. **(C)**

Considering the whole period of rainfall to be the period of rainfall excess.

$$\phi\text{-index} = \frac{P-Q}{t}$$

$$p = \text{Total rainfall} = (7+18+25+17+11+3)\times 1 = 81\,\text{mm}$$

Q = Runoff = 39 cm and t = Duration of rainfall = 6 hrs.

$$\therefore \quad \phi\text{-index} = \frac{81-39}{6} = 7\,\text{mm/hr}$$

Since first and last hours are not period of rainfall excess as rainfall intensity $\leq$ ϕ-index.

$$\therefore \quad \phi\text{-index} = \frac{(81-7-3)-39}{4} = \frac{32}{4} = 8\,\text{mm/hr}$$

Hence, the correct option is (C).

3.5 The penman's evapo-transpiration equation is based on

(A) Water budget method

(B) Energy balance method

(C) Mass transfer method

(D) Energy balance and mass transfer approach

Sol. **(D)**

Penman's Equation : Penman's equation is based on sound theoretical reasoning and is obtained by combination of energy and mass transfer approach.

$$PET = \frac{AH_n + E_a\gamma}{A+\gamma}$$

PET = Daily potential evapotranspiration (in mm per day)

A = Slope of the saturation vapour pressure vs. temperature curve at the mean air temperature (in mm of Hg per ^{0}C)

H_n = Net radiation, E_a = Parameter including wind velocity and saturation deficit and

γ = Psychromrtic constant = 0.49 mm of Hg/^{0}C

Hence, the correct option is (D).

ESE 2003

3.6 A 6-hour storm with hourly intensities of 7, 18, 25, 12, 10 and 3 mm per hour produced a run - off of 33 mm. then the ϕ - index is

(A) 7 mm/h (B) 3 mm/h (C) 10 mm/h (D) 8 mm/h

Sol. **(D)**

Considering the whole period of rainfall to be the period of rainfall excess.

$$\phi\text{-index} = \frac{P-Q}{t}$$

4 Surface Water Hydrology (Runoff)

ESE 1999

4.1 In a flow-mass curve study, the demand line drawn from a ridge does not intersect the mass curve again. This implies that

(A) The reservoir is not full at the beginning

(B) The storage is not adequate

(C) The demand cannot be met by the inflow as the reservoir will not refill

(D) The reservoir is wasting water by spill.

Sol. **(C)**

If mass curve does not intersect the demand line drawn from ridge. It shows that rate of inflow is always less than or equal to rate of demand, so reservoir will not refill hence the demand cannot be met by the inflow.

Hence, the correct option is (C).

ESE 2000

4.2 If a tangent drawn parallel to the demand line drawn from a ridge point of a mass-curve does not intersect the mass curve again it can be inferred that the

(A) Frequency of flood entering into the reservoir is less

(B) Inflow into the reservoir cannot meet the demand

(C) Reservoir is overflowing resulting into wastage

(D) Reservoir can meet higher demand

Sol. **(B)**

Mass-curve is the plot between cumulative inflow volume and the time. If a tangent parallel to the demand line is drawn from a ridge point of a mass-curve and it does not intersect the mass curve again it means the cumulative inflow volume will never be equal to cumulative demand volume and thus demand cannot be met by inflow.

Hence, the correct option is (B).

ESE 2002

4.3 Consider the following statements :

1. An ephemeral stream is one which has a base flow contribution

2. Flow characteristics of a stream depend upon rainfall and catchment characteristics and also the climatic factors which influence evapotranspiration
3. Sequent peak algorithm is used for estimating runoff from rainfall

Which of these statements is/are correct?

(A) 1,2 and 3 (B) 1 and 3 (C) 2 and 3 (D) 2 alone

Sol. **(D)**

Flow characteristics of a stream depend upon rainfall and catchment characteristics and also on the climatic factors as it influence evapotranspiration.

Based on the study of hydrographs, streams are classified as :

1. **Perennial stream :** one which always carries some flow. Ground water contributes throughout the year.
2. **Intermittent stream :** one which has limited contribution from the groundwater. During dry season the water table falls below the stream bed and it dries up.
3. **Ephemeral stream :** one which does not have any base-flow contribution. The stream dries up soon after the end of storm flow.

Sequent peak algorithm uses a flow mass curve with a variation of the arithmetic calculation to suit for the analysis of large data to determine the storage capacity of a reservoir.

Hence, the correct option is (D).

4.4 The following items related to hydrologic requirements in hydropower system. Match **List- I** with **List-II** and select the correct answer :

List-I		List-II	
A.	Stream flow in order of magnitude is plotted as ordinate and percent of time as abscissa	1.	Mass curve
B.	Cumulative value of stream flow is plotted against time for whole period of record	2.	Flow duration curve
C.	Plot of available power against percent of time	3.	Hydrograph
D.	Plot of flow in a stream against time at specific interval	4.	Power duration curve

Codes :

	A	B	C	D
(A)	2	3	4	1
(B)	4	1	2	3
(C)	2	1	4	3
(D)	4	3	2	1

Sol. **(C)**

A flow duration curve, also called as discharge frequency curve, is a curve plotted between stream flow Q and percent of time the flow is equalled or exceeded. It is used to study the variability of stream flow over a water year.

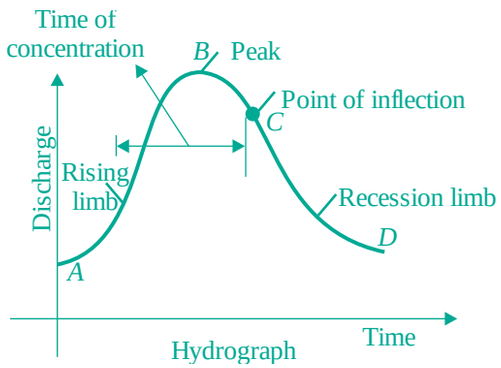
Mass curve method :

- This method is also known as the rippl mass curve method after the developer of this method. This is a simple method commonly used to estimate the required storage capacity of a reservoir in the project planning stage.
- The method uses the most critical period of recorded flow to compute storage.
- The critical period is defined as the duration in which a full reservoir depletes and passes through various states and empties without spilling. In the methods based on the essential period concept, a sequence of stream flows containing a critical period is routed through an initially full reservoir in presence of specified demands.
- The reservoir capacity is obtained by finding the maximum difference between cumulative inflows and cumulative demand curves.
- To determine the minimum required storage, the mass curve of inflow and the mass curve of demand are accumulated separately.
- For a constant draft the mass curve of demand will be a straight line having a slope equal to the demand rate. Now. at each high point on the mass inflow curve, a line is drawn parallel to the mass curve of demand and is extended until it meets the mass curve of inflows.

Hydrograph :

Hydrograph is a plot between discharge and time at any given section of a river, channel, etc. It is a response of a given catchment to the rainfall input.

The shape of rising limb of a hydrograph depends on both catchment characteristic and rainfall characteristic. The shape of falling limb of a hydrograph depends only on catchment characteristic.



Hence, the correct option is (C).

ESE 2003

4.5 Flow duration curve is a plot of

(A) Flow against its time of occurrence in chronological order

(B) Flow in ascending order against percentage time in chronological order

(C) Flow that equalled or exceeded against percentage time

(D) Flow against duration of time for which it is sustained

5 Stream Flow Measurement

ESE 2001

5.1 As a flood wave passes a given section of a river, the time of occurrence of the maximum stage and that of the maximum discharge will be such that

(A) The maximum discharge passes down before the maximum stage is attained

(B) The maximum stage is attained before the maximum discharge passes down

(C) The two events occur simultaneously

(D) No specific sequence would be universally assignable

Sol. **(A)**

As a flood wave passes a given section of a river, first the maximum discharge will pass by and afterwards maximum stage will be attained due to the effect of storage.

Hence, the correct option is (A).

ESE 2002

5.2 The slope area method is extensively used in

(A) Development or rating curve

(B) Estimation of flood discharge based on high-water marks

(C) Cases where shifting control exists

(D) Cases where back-water effect is present

Sol. **(B)**

The slope area method is of particular use in estimating the flood discharge in a river by past records of stages at different sections. Floods leave traces of peak elevations called high water marks in their wake.

Hence, the correct option is (B).

ESE 2006

5.3 In the case of large rivers, a number of equidistant vertical sections of the total width of flow are identified, for the purpose of finding by numerical integration, the total discharge on any day. On each section, the mean velocity is taken as the arithmetic average of two typical depths on that section. Then the mean velocity is worked out for that section. Usually, the mean velocity of any section, corresponds to which one of the following?

(V represents the point velocity at the given section and the depth such as 0.1d, 0.2d.... etc.)

(A) $\frac{V_{0.1d}+V_{0.9d}}{2}$ (B) $\frac{V_{0.2d}+V_{0.8d}}{2}$ (C) $\frac{V_{0.3d}+V_{0.7d}}{2}$ (D) $\frac{V_{0.4d}+V_{0.6d}}{2}$

Sol. **(B)**

- In moderately deep streams the velocity is observed at two points and average velocity is given as

$$\bar{V}=\frac{V_{0.2d}+V_{0.8d}}{2}$$

- In shallow streams of depth upto 3m, $\bar{V}=V_{0.6}$
- In rivers having flood flow, $\bar{V}=KV_s$

Where V_s is surface velocity and k is a reduction factor, having value in the range of 0.85 to 0.95.

Hence, the correct option is (B).

5.4 Match **List-I** with **List-II** and select the correct answer using the code given below the Lists :

List-I		List-II	
A.	Location	1.	Perennial
B.	Stability	2.	Degrading
C.	Variation of discharge	3.	Tidal
D.	Plan form	4.	Braided

Codes :

	A	B	C	D
(A)	4	2	1	3
(B)	3	1	2	4
(C)	4	1	2	3
(D)	3	2	1	4

Sol. **(D)**

Classification of rivers :

(A) Based on location of reach :

1. Mountain rivers
2. Rivers in flood plains
3. Delta rivers
4. Tidal rivers

(B) Classification of alluvial rivers based on stability :

1. Stable meandering rivers
2. Aggrading rivers
3. Degrading rivers

(C) Based on variation of discharge :

1. Perennial river
2. Non-perennial river
3. Flashy river
4. Virgin river

(D) Based on plan-form

1. Straight rivers
2. Meandering rivers
3. Braided rivers

Hence, the correct option is (D).

5.5 Match **List-I (Technique/Principle)** with **List-II (Purpose)** and select the correct answer using the code given below the Lists :

List-I		List-II	
A.	ϕ -index	1.	Dependable flow
B.	Slope-area method	2.	Reservoir regulation
C.	Flow duration curve	3.	Steady stream discharge determination
D.	Dilution technique	4.	Run-off volume
		5.	Unsteady stream discharge determination

Codes :

	A	**B**	**C**	**D**
(A)	3	5	1	4
(B)	4	1	2	3
(C)	3	1	2	4
(D)	4	5	1	3

Sol. **(D)**

- Slope area method and Dilution technique both are methods of stream discharge determination. Dilution method of gauging is based on the assumption of steady flow. If the flow is unsteady and the flow rate changes appreciably during gauging, there will be change in the storage volume in the reach and the steady state continuity equation will not be valid. Slope area method is generally used to estimate the discharge due to flood i.e., unsteady stream discharge.
- ϕ -index in an infiltration index using which direct runoff depth can be determined.
- Flow duration curve of a stream is a plot of discharge against the percent of time the flow was equalled or exceeded.

Some of the important uses of flow duration curve are :

1. In evaluating various dependable flows in planning of water resources projects.
2. In flood control studies.
3. In the design of drainage systems
4. In evaluating the hydropower potential of a river.

Hence, the correct option is (D).

5.6 In a river carrying a discharge of 142 m^3/s, the stage at station A was 3.6 m and the water surface slope was 1 in 6000. If during a flood, the stage at A was 3.6 m and the water surface slope was 1 in 3000, what was the flood discharge (approximately)?

(A) 284 m^3/s (B) 200 m^3/s (C) 164 m^3/s (D) 96 m^3/s

Sol. **(B)**

Since, discharge, $Q = K\sqrt{S}$

i.e., $Q \propto \sqrt{S}$

$\therefore$ $\dfrac{Q_1}{Q_2} = \sqrt{\dfrac{S_1}{S_2}}$

6 Surface Water Hydrology Hydrograph

ESE 1995

6.1 Which one of the following constitute the basic assumption of Unit Hydrograph theory?

(A) Non-linear response and time invariance

(B) Non- linear time variance and linear response

(C) Linear response and linear time variance

(D) Time invariance and linear response

Sol. **(D)**

Following are the assumptions of Sherman's Unit Hydrograph Theory :

1. Time invariance
2. Linear response
3. Fixed Base-period. The base periods of the direct runoff hydrographs produced by effective rainfall of same duration (though the intensities may be different) are also same.
4. Rainfall excess is assumed to be uniformly distributed over the entire catchment area
5. Intensity of rainfall excess is assumed to be constant during the entire duration.

Out of these the assumption of time invariance and linear response are most important.

Hence, the correct option is (D).

ESE 1996

6.2 The following four hydrological features have to be estimated or taken as inputs before one can compute the flood hydrograph at any catchment outlet.

1. Unit hydrograph
2. Rainfall hydrograph
3. Infiltration index
4. Base flow

The correct order in which they have to be employed in the computations is

(A) 1,2,3,4 (B) 2,1,4,3 (C) 2,3,1,4 (D) 4,1,3,2

Sol. **(C)**

In order to compute the flood hydrograph at any catchment outlet first with the help of a known rainfall hydrograph of any duration and the infiltration index for that catchment, the unit hydrograph of same duration is derived by dividing the ordinates of rainfall hydrograph by excess rainfall depth which is obtained as follows :

Excess rainfall depth = Total rainfall depth ϕ-index $\times$ Duration of rainfall.

Then from the obtained unit hydrograph another unit hydrograph of a duration equal to that of flood duration is computed and with its help flood hydrograph is obtained knowing base flow.
Hence, the correct option is (C).

ESE 1997

6.3 The following steps are involved in arriving at a unit hydrograph-
1. Estimating the surface runoff in depth.
2. Estimating the surface runoff in volume
3. Separation of base flow
4. Dividing surface runoff ordinates by depth of runoff

The correct sequence of these steps is
(A) 3,2,1,4 (B) 2,3,4,1 (C) 3,1,2,4 (D) 4,3,2,1

Sol. **(A)**

In order to derive a Unit hydrograph from a flood hygrograph first of all base flow is separated from flood hydrograph to obtain the direct runoff hydrograph (surface runoff hydrograph). Then surface runoff volume is computed which is equal to the area under direct runoff hydrograph. By dividing the surface runoff volume by the catchment area surface runoff depth is obtained. Now Unit hydrograph is obtained by dividing the surface runoff ordinates by surface runoff depth.

Note : If we neglect interflow (as its contribution is very less to direct runoff), direct runoff = surface runoff.

Hence, the correct option is (A).

ESE 1999

6.4 Match **List-I (Name of Scientists)** with **List-II (Contribution to field of Hydrology)** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	Dalton	1.	Unit hydrograph
B.	Snyder	2.	Evaporation
C.	Blaney-Criddle	3.	Empirical flood formula
D.	Sherman	4.	Synthetic unit hydrograph
		5.	Consumptive use equation

Codes :

	A	B	C	D
(A)	2	3	5	1
(B)	1	4	3	2
(C)	2	4	5	1
(D)	1	3	4	5

Sol. **(C)**

- Dalton gave the law of evaporation which states that rate of evaporation is proportional to the difference between the saturation vapor pressure at the water temperature (e_w) and the actual vapour pressure in the air (e_a) i.e., $E = k(e_w - e_a)$.

- Snyder gave the synthetic unit hydrograph theory.
- Blaney-criddle gave the empirical equation to find potential evapotranspiration which is also called consumptive use. So equation is also called consumptive use equation.
- Unit hydrograph theory was given by Sherman.

Hence, the correct option is (C).

6.5 If a 4-hour unit hydrograph of a certain basin has a peak ordinate of 80 , the peak ordinate of a 2 - hour unit hydrograph for the same basin will be

(A) Equal to 80 (B) Greater than 80 (C) Less than 80 (D) Between 40

Sol. **(B)**

Peak ordinate decreases with increase in the duration of unit hydrograph for the same basin. So, a 2-hour unit hydrograph will have peak ordinate greater than that of a 4-hour unit hydrograph.

Hence, the correct option is (B).

Key Point

Unit Hydrograph : It is a DRH resulting from one unit depth of rainfall excess (Direct runoff) occurring uniformly over the basin at a uniform rate for a specified duration of D' hours.

The theory of unit hydrograph was developed by Sherman in the year 1932 and assumptions are given below :

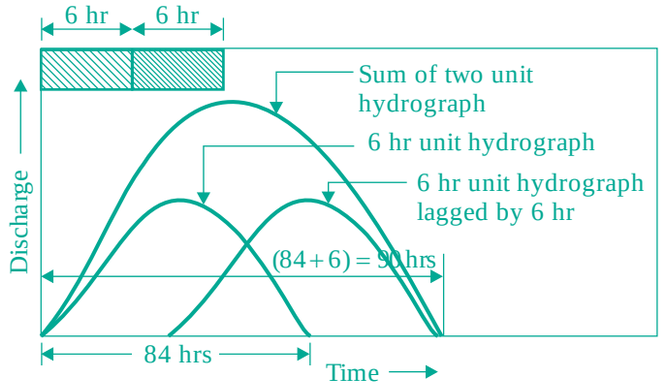
1. **Time invariance :** According to this assumption, the DRH for a given effective rainfall is always the same in the catchment irrespective of the time, when the rainfall or storm takes place.
2. **Linear response :** This is the single most important assumption in the theory of unit hydrograph. According to this assumption, any change in the input value is proportionately reflected in the output value.

ESE 2000

6.6 If the base period of a 6-hour unit hydrograph of a basin is 84 hours, then a 12-hours unit hydrograph derived from this unit hydrograph will have a base period of

(A) 72 hours (B) 78 hours (C) 84 hours (D) 90 hours

Sol. **(D)**



7 Floods

ESE 1997

7.1 Probability of a 10 year flood to occur at least once in the next 4 years is

(A) 25% (B) 35% (C) 50% (D) 65%

Sol. **(B)**

Probability of an event occurring at least once in n successive years

$$P_1 = 1-(1-P)^n$$

Where, $P = \frac{1}{T} = \frac{1}{10} = 0.1$ and $n = 4$

$\therefore$ $$P_1 = 1-(1-0.1)^4 = 1-0.9^4 = 0.3439 = 34.39\% = 35\%$$

Hence, the correct option is (B).

7.2 The standard project flood is

(A) Derived from the probable maximum precipitation in the region.

(B) Derived from the severe most meteorological conditions anywhere in the country

(C) The flood with return period of 1000 years

(D) The same as the probable maximum flood

Sol. **(B)**

- Standard project flood is the estimate of the flood likely to occur from the most severe combination of the meteorological and hydrological conditions that are reasonably applicable to the region but excluding extremely rare combinations.
- If probable maximum precipitation in the region is estimated, then it can be used to provide an estimate of the probable maximum flood, which is physically possible in the region as a result of severe most combinations, including rare combinations of meteorological and hydrological factors. Hence probable maximum flood (PMF) is derived from the probable maximum precipitation. In a region SPF is about 40 to 60% of the PMF for a given drainage basin.

Hence, the correct option is (B).

ESE 1999

7.3 Consider the following statements :

1. A 100 year flood discharge is greater than a 50 year flood discharge
2. 90% dependable flow is greater than 50% dependable flow
3. Evaporation from salt-water surface is less than that from fresh-water surface

Which of these statements are correct?

(A) 1 and 2 (B) 2 and 3 (C) 1 and 3 (D) 1,2 and 3

Sol. **(C)**

Flood discharge magnitude increases with increase in the return period. So, a 100 year flood discharge will be greater than a 50 year flood discharge.

If p is the probability of exceedance of a flood discharge magnitude, its % dependability is said to be 100. It means a 90% dependable flow has probability= 0.9 of being equaled or exceeded and return period= 1/p = 1/0.9 = 1.11 years.

50% dependable flow has probability = 0.5 and return period = 1/0.5 = 2 years.

Since return period of 50% dependable flow is greater than that of 90% dependable flow.

Hence, 50% dependable flow is greater than 90% dependable flow.

When a solute is dissolved in water, the vapour pressure of the solution is less than that of pure water and hence causes reduction in the rate of evaporation. Under identical conditions evaporation, from sea-water is 2-3% less than that from fresh water.

Hence, the correct option is (C).

7.4 A culvert is designed for a peak flow Q_p on the basis of rational formula. If a storm of the same intensity as used in the design and twice the duration occurs, then the resulting peak discharge will be

(A) Q_p (B) $\frac{Q_p}{2}$ (C) $\sqrt{2}Q_p$ (D) $2Q_p$

Sol. **(A)**

Rational formula, $Q_P = CAi;\ \text{for}\ t > t_c$

Where Q_P is peak flow, when rainfall continues beyond time of concentration (t_c). It is obvious for time of rainfall $t > t_c$, runoff will be constant for the same storm intensity.

Hence, the correct option is (A).

ESE 2001

7.5 The probability that a 100 year flood is equaled or exceeded, at least once in 100 years is

(A) 99% (B) 64% (C) 36% (D) 1%

Sol. **(B)**

The probability of the event occuring at least once in n successive years

$$P_1 = 1-(1-P)^n$$

Where, $n = 100$ year and $P = \frac{1}{T} = \frac{1}{100} = 0.01$

$\therefore$ $P_1 = 1-(1-0.01)^{100} = 0.6339 = 63.39\% \approx 64\%$

Hence, the correct option is (B).

ESE 2003

7.6 Match **List-I (Floods)** with **List-II (Parameters)** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	Standard project flood (SPF)	1.	Includes catastrophic floods
B.	Maximum probable flood (MPF)	2.	Includes floods of severe conditions
C.	Design flood	3.	Peak flow obtained from observed data
D.	Maximum flood	4.	Flood of desired recurrence interval

Codes : **A B C D**

(A) 2 1 4 3

(B) 1 2 3 4

(C) 2 1 3 4

(D) 1 2 4 3

Sol. **(A)**

(i) **Standard project flood (SPF) :** This is the estimate of the flood likely to occur from the most severe combination of the meterological and hydrological conditions, which are reasonably characteristic of the drainage basin being considered, but excluding extremely rare combination.

(ii) **Maximum probable flood (MPF) :** This differs from the SPF in that it includes the extremely rare and catastrophic floods and is usually confined to spillway design of very high dams. The SPF is usually around 80% of the MPF for the basin.

(iii) **Design flood :** It is the flood adopted for the design of hydraulic structure like spillways, bridge openings, flood banks, etc. It may be the MPF or SPF or a flood of any desired recurrence interval depending upon the degree of flood protection to be offered and cost economics of construction of structures.

(iv) **Maximum flood :** Correspond to peak flow obtained from observed data.

Hence, the correct option is (A).

ESE 2004

7.7 A bridge has an expected life of 50 years and is designed for a flood magnitude of return period 100 years. What is the risk associated with this hydrologic design?

(A) $1-(0.99)^{50}$ (B) $(0.5)^{50}$ (C) $(0.99)^{50}$ (D) $(0.99)^{100}$

8 Flood Routing

ESE 1996

8.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	Conservation Reservoirs	1.	Uncontrolled outlets
B.	Retarding basins	2.	Flood-fighting
C.	Flood plains	3.	Temporary storage of flood water
D.	Flood walls	4.	Controlled outlets

Codes :

	A	**B**	**C**	**D**
(A)	1	4	3	2
(B)	1	4	2	3
(C)	4	1	3	2
(D)	4	1	2	3

Sol. **(C)**

Depending upon the purpose served, reservoirs are classified as :

1. Storage (or conservation) reservoirs
2. Flood control reservoirs

Storage or conservation reservoirs are used to conserve water. They are constructed to store the water in rainy season and to release it later when the river flow is low. They are provided with gated spillways and sluiceways and hence are regulated and has controlled outlet.

Although they are constructed for storing water for various purposes, incidentally they also help in moderating floods and reducing the flood damage to some extent. However, they are not designed as flood control reservoirs.

Flood control reservoirs are of two types :

1. Detention reservoirs (or detention basins) : These are regulated by gates and thus has controlled outlet.
2. Retarding reservoirs (or retarding basins) : These are ungated and has uncontrolled outlet.

Flood plains are formed by deposition of sediments which usually occurs due to intermittent over flows of the stream above its banks.

Flood walls are masonry structures used for protection of the land and property from floods by confining it to a fixed course and limited cross-sectional width.

Hence, the correct option is (C).

8.2 The construction of impounding reservoir is required when

(A) Average annual flow in the stream is lower than average demand.

(B) The rate of flow in the stream, in dry season is more than the demand

(C) The rate of flow in the stream, in dry season is less than the demand

(D) The rate of flow in the stream is equal to the demand

Sol. **(C)**

A reservoir with outlets controlled by gates that release stored surface water as needed in a dry season, may also store water for domestic or industrial use or for flood control.

Hence, the correct option is (C).

ESE 1999

8.3 The trap efficiency of a reservoir is a function of

(A) Inflow into the reservoir

(B) Ratio of inflow to storage capacity

(C) Ratio of reservoir capacity to inflow

(D) Reservoir capacity

Sol. **(C)**

Trap efficiency is defined as the percentage of the sediment deposited in the reservoir. Trap efficiency has been found to be a function of capacity-inflow ratio.

Trap efficiency, $\eta = f\left(\frac{\text{Capacity of reservoir}}{\text{Total inflow of water}}\right)$

If capacity-inflow ratio decreases, trap efficiency decreases.

Hence, the correct option is (C).

8.4 In a linear reservoir, the

(A) Volume varies linearly with elevation

(B) Outflow rate varies linearly with storage

(C) Storage varies linearly with time

(D) Storage varies linearly with inflow rate

Sol. **(B)**

In a linear reservoir, storage is a function of outflow discharge only i.e. $S = KQ$.

Hence, the correct option is (B).

ESE 2001

8.5 The life of a reservoir is determined by its capacity(C), volume of annual inflow into the reservoir (I) and concentration of sediment in the incoming flow(C_s). Life will be more if

(A) C, I and C_s are high

(B) C, and I are high but C_s is low

(C) C is high but I and C_s are low

(D) C, I and C_s are low

Sol. **(B)**

The life of a reservoir is determined by knowing the rate of sedimentation which depends on trap efficiency. Trap efficiency is percentage of total inflow sediments which are retained in the reservoir. From observations of the rate of sedimentation of existing reservoirs, it has been found that the trap efficiency is a function of ratio of reservoir storage capacity to inflow.

9 Ground Water Hydrology

ESE 1996

9.1 The yield of a well depends upon

(A) Permeability of soil
(B) Area of aquifer opening into the wells
(C) Actual flow velocity
(D) All of the above

Sol. **(D)**

Yield of a well is the ratio of volume of water in an aquifer that can be extracted by the force of gravity (or by pumping from wells) to the total volume of the saturated aquifer. It depends upon :

1. Thickness and type of aquifer
2. Particle size and the permeability of the aquifer material
3. Cross-sectional area of well
4. Drawdown
5. Actual flow velocity (inferred)

Hence, the correct option is (D).

ESE 1999

9.2 Water present in an artesian aquifer is usually

(A) At sub atmospheric pressure
(B) At atmospheric pressure
(C) At 0.5 times of atmospheric pressure
(D) Above atmospheric pressure

Sol. **(D)**

Confined aquifer is also called artesian aquifer, water present in it is at a pressure above atmospheric pressure as it is confined between two impermeable stratas and is not exposed to atmospheric pressure.

Hence, the correct option is (D).

9.3 Match **List -I** with **List-II** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	Specific yield	1.	Volume of water retained per unit volume of aquifer.
B.	Specific capacity	2.	Volume of water drained by gravity per unit drained volume of aquifer.
C.	Specific retention	3.	Difference of porosity & specific storage.
D.	Specific storage	4.	Well yield per unit draw-down.
		5.	Volume of water released from unit volume of aquifer for unit decline in piezometric head.

Codes :	A	B	C	D
(A)	2	4	1	5
(B)	4	2	3	5
(C)	2	5	1	4
(D)	4	2	3	1

Sol. **(A)**

Specific yield is the ratio of volume of water in an aquifer that can be extracted by the force of gravity to the total volume of the saturated aquifer.

Specific retention is the ratio of volume of water retained in an aquifer against the force of gravity to the total volume of the saturated aquifer.

Specific yield + Specific retention = Porosity Specific capacity of a well is its yield per unit drawdown.

Specific storage is the volume of water released from unit surface area of aquifer when piezometric head drops by unity.

Hence, the correct option is (A).

9.4 An aquifer confined at top and bottom by impermeable layers is stratified into three layers as follows :

Layer	Thickness (m)	Permeability (m/day)
Top layer	4	30
Middle layer	2	10
Bottom layer	6	20

The transmissivity (m^2/day) of the aquifer is

(A) 260 (B) 227 (C) 80 (D) 23

Sol. **(A)**

Transmissivity, $T = kD$

Equivalent k in x-direction, $k_{eq} = \dfrac{\sum kD}{\sum D}$

Hence equivalent transmissivity $= \sum kD$

$$k_{eq}(D_1 + D_2 + D_3) = \frac{\sum kd}{\sum D}(\sum D) = \sum kD$$

$$k_{eq}(D_1 + D_2 + D_3) = (4 \times 30) + (2 \times 10) + (6 \times 20) = 120 + 20 + 120 = 260$$

Hence, the correct option is (A).

ESE 2000

9.5 Specific capacity of a well is the

(A) Volume of water that can be extracted by the force of gravity from a unit volume of aquifer

(B) Discharge per unit drawdown of the well

(C) Drawdown per unit discharge of the well

(D) Rate of flow through a unit width and entire thickness of aquifer

Sol. **(B)**

Specific capacity of a well is its yield per unit drawdown.

Hence, the correct option is (B).

ESE 2001

9.6 Consider the following statements :

Assertion (A) : The available yield of a tubewell can be doubled by doubling the diameter of the well.

Reason (R) : The yield of a tubewell varies inversely with the logarithm of the reciprocal of the diameter of the well.

Of these statements

(A) Both A and R are true and R is correct explanation of A

(B) Both A and R are true but R is not a correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

Sol. **(D)**

As the flow in the tubewell is radial, the Dupit. Theim's equations can be used to estimate the yield of a tubewell as given below :

For unconfined aquifer : $Q = \dfrac{\pi k(H^2 - h_w^2)}{\ln\left(\dfrac{R}{r_w}\right)}$

For confined aquifer : $Q = \dfrac{2\pi kB(H - h_w)}{\ln\left(\dfrac{R}{r_w}\right)}$

In both cases yield of a tubewell varies inversely with the logarithm of the reciprocal of the diameter of the well. So, yield of well will not be doubled by doubling the diameter of well.

Hence, the correct option is (D).

ESE 2002

9.7 Match **List-I (Equation)** with **List-II (Applicability of principle of equation)** and select the correct answer using the codes given below the lists :

List-I		List-II	
A.	Theim's equation	1.	Is based on energy conservation principle.
B.	Dupit's equation	2.	Is based on mass conservation principle.
C.	Bernoulli's equation	3.	Is applicable to steady flow towards a well in a confined aquifer.
D.	Continuity equation	4.	Is applicable to steady flow in an unconfined aquifer.

Codes :	A	B	C	D
(A)	4	3	2	1
(B)	3	4	2	1
(C)	4	3	1	2
(D)	3	4	1	2

Sol. **(D)**

Popularly the equation of discharge for the steady flow in a confined aquifer is called Theim's equation. Dupit's equation is the equation for steady flow in unconfined aquifer. Bernoulli's equation is based on energy conservation principle and the continuity equation is based on mass conservation principle.

Hence, the correct option is (D).

9.8 The performance of a well is measured by

(A) Specific capacity (B) Specific yield

(C) Storage coefficient (D) Permeability coefficient

Sol. **(A)**

The performance of a well is measured by its specific capacity which is the discharge of the well per unit drawdown. The water yielding capacity of a confined aquifer is expressed by storage coefficient and that of unconfined aquifer by specific yield.

Hence, the correct option is (A).

ESE 2003

9.9 Consider the following statements :

A well development

1. Involves reversal of flow through the well screen
2. Increases permeability towards the well
3. Decreases permeability towards the well
4. Is continued till sand/silt free water is pumped out

Which of these statements is/are correct?

(A) 1,3 and 4 (B) 1, 2 and 4 (C) 3 only (D) 1 and 4

Sol. **(B)**

The basic principle in well development is to cause reversal of flow through the screen openings, that will rearrange the aquifer particles. This is essential to break down bridging of the groups of particles, which is done by reversal of flow.

The purpose of well development is to ensure removal of fine grained sediments (fines) from the vicinity of the well screen. This allows the water to flow freely from the formation into the well, and also reduces the turbidity of the water during sampling. The most common well development methods are: surging, jetting, over pumping, and bailing. It is done to

- Restore an aquifer/well.
- Reduce head loss by increasing permeability.
- Increases well efficiency.
- Reduce drawdown and cost of extracting groundwater.

Hence, the correct option is (B).