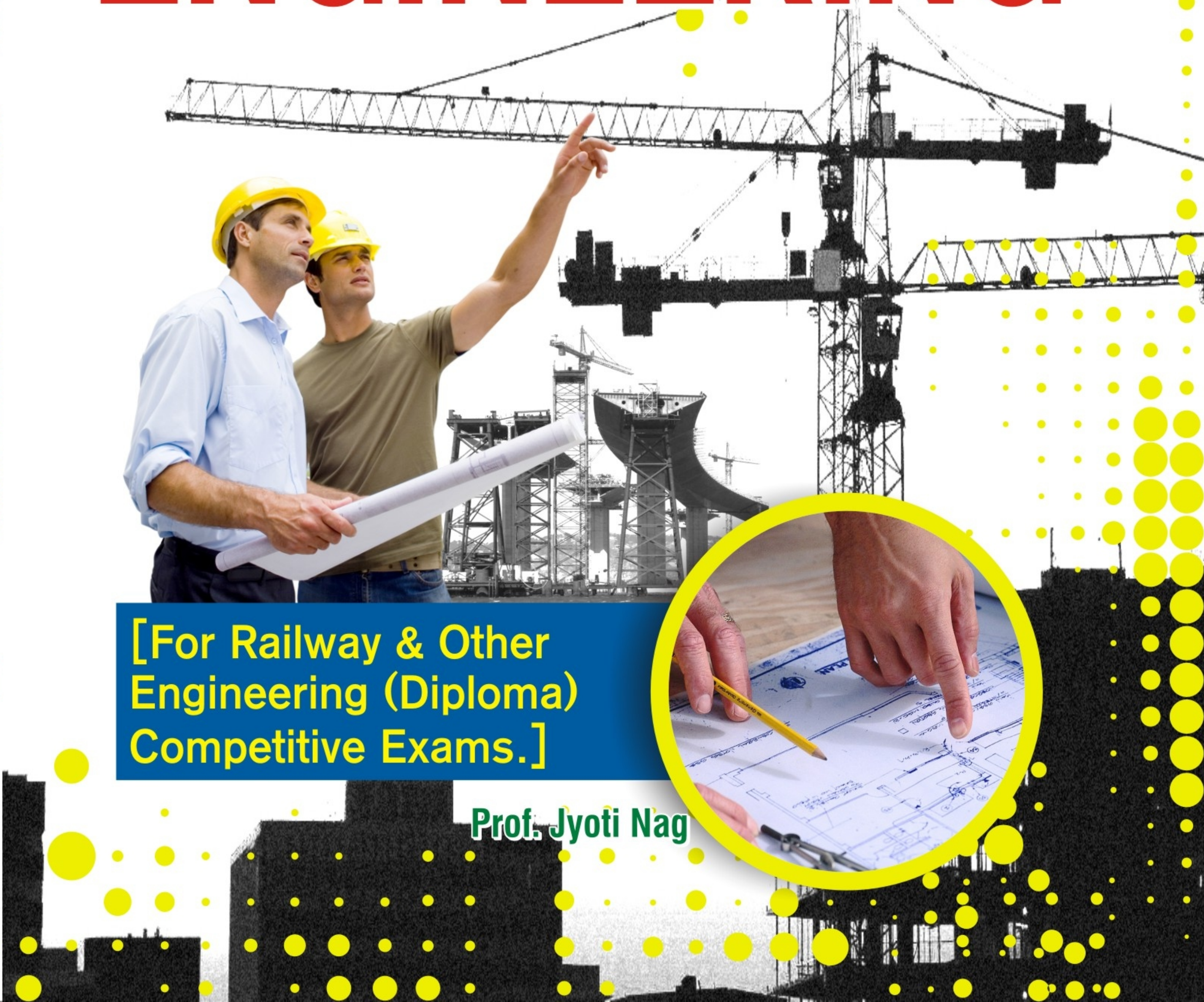
UPKAR'S

A HANDBOOK ON CIVIL ENGINEERING



[For Railway & Other Engineering (Diploma) Competitive Exams.]

Prof. Jyoti Nag

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By

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A Handbook on CIVIL ENGINEERING

1. Introduction of Civil Engineering

- Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings.
- Civil engineering is the second-oldest engineering discipline after military engineering, and it is defined to distinguish non-military engineering from military engineering. It is traditionally broken into several sub-disciplines including architectural engineering, environmental engineering, geotechnical engineering, geophysics, geodesy, control engineering, structural engineering, earthquake engineering, transportation engineering, earth science, atmospheric sciences, forensic engineering, municipal or urban engineering, water resources engineering, materials engineering, offshore engineering, aerospace engineering, quantity surveying, coastal engineering, surveying, and construction engineering.
- Civil engineering takes place in the public sector from municipal through to national governments, and in the private sector from individual homeowners through to international companies.
- Engineering has been an aspect of life since the beginnings of human existence. The earliest practice of civil engineering may have commenced between 4000 and 2000 BC in Ancient Egypt and Mesopotamia when humans started to abandon a nomadic existence, creating a need for the construction of shelter. During this time, transportation became increasingly important leading to the development of the wheel and sailing.
- Until modern times there was no clear distinction between civil engineering and architecture, and the term engineer and architect were mainly geographical variations referring to the same occupation, and often used interchangeably.
- The construction of pyramids in Egypt (circa 2700–2500 BC) were some of the first instances of large structure constructions. Other ancient historic civil engineering constructions include the Qanat water management system (the oldest is older than 3000 years and longer than 71 km,) The Romans developed civil structures throughout their empire, including especially aqueducts, insulae, harbors, bridges, dams and roads.
- In the 18th century, the term civil engineering was coined to incorporate all things civilian as opposed to military engineering The first self-proclaimed civil engineer was John Seaton, who constructed the Eddy stone.
- In 1818 the Institution of Civil Engineers was founded in London, and in 1820 the eminent engineer Thomas Telford became its first president. The institution received a Royal Charter in 1828, formally recognising civil engineering as a profession.
- Its charter defined civil engineering as:
- the art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters and lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and application of machinery, and in the drainage of cities and towns.
- The first private college to teach Civil Engineering in the United States was Norwich University, founded in 1819 by Captain Alden Partridge. The first degree in Civil Engineering in the United States was awarded by Rensselaer Polytechnic Institute in 1835.
- Civil engineering is the application of physical and scientific principles for solving the problems of society, and its history is intricately linked to advances in understanding of physics and mathematics throughout history. Because civil engineering is a wide ranging profession, including several separate specialized sub-disciplines, its history is linked to knowledge of structures, materials science, geography, geology, soils, hydrology, environment, mechanics and other fields.
- Throughout ancient and medieval history most architectural design and construction was carried out by artisans, such as stonemasons and carpenters, rising to the role of master. Knowledge was retained in guilds and seldom supplanted by advances. Structures, roads and infrastructure that existed were repetitive, and increases in scale were incremental.
- One of the earliest examples of a scientific approach to physical and mathematical problems applicable to civil engineering is the work of Archimedes in the 3rd century BC, including Archimedes Principle, which underpins our understanding of buoyancy, and practical solutions such as Archimedes' screw.
- Brahmagupta, an Indian mathematician, used arithmetic in the 7th century AD, based on Hindu-Arabic numerals, for excavation (volume) computations.
- Civil engineers typically possess an academic degree in civil engineering. The length of study is three to five

years, and the completed degree is designated as a bachelor of engineering, or a bachelor of science. The curriculum generally includes classes in physics, mathematics, project management, design and specific topics in civil engineering.

- In most countries, a bachelor's degree in engineering represents the first step towards professional certification, and a professional body certifies the degree program. After completing a certified degree program, the engineer must satisfy a range of requirements (including work experience and exam requirements) before being certified.
- In general, civil engineering is concerned with the overall interface of human created fixed projects with the greater world. General civil engineers work closely with surveyors and specialized civil engineers to design grading, drainage, pavement, water supply, sewer service, electric and communications supply, and land divisions.
- General engineers spend much time visiting project sites, developing community consensus, and preparing construction plans. General civil engineering is also referred to as site engineering, a branch of civil engineering that primarily focuses on converting a tract of land from one usage to another.
- Civil engineers apply the principles of geotechnical engineering, structural engineering, environmental engineering, transportation engineering and construction engineering to residential, commercial, industrial and public works projects of all sizes and levels of construction.
- Materials science is closely related to civil engineering. Material engineering studies fundamental characteristics of materials, and deals with ceramics such as concrete and mix asphalt concrete, strong metals such as aluminium and steel, and polymers including polymethylmethacrylate (PMMA) and carbon fibers.
- Materials engineering also involves protection and prevention (paints and finishes). Alloying combines two types of metals to produce another metal with desired properties. It incorporates elements of applied physics and chemistry.
- Coastal engineering is concerned with managing coastal areas. In some jurisdictions, the terms sea defence and coastal protection mean defence against flooding and erosion, respectively. The term coastal defence is the more traditional term, but coastal management has become more popular as the field has expanded to techniques that allow erosion to claim land.
- Construction engineering involves planning and execution, transportation of materials, site development based on hydraulic, environmental, structural and geotechnical engineering. As construction firms tend to have higher business risk than other types of civil engineering firms do, construction engineers often engage in more business-like transactions, for example, drafting and reviewing contracts, evaluating logistical operations, and monitoring prices of supplies.
- Earthquake engineering involves designing structures to withstand hazardous earthquake exposures. Earthquake engineering is a sub-discipline of structural engineering. The main objectives of earthquake engineering are to understand interaction of structures on the shaky ground; foresee the consequences of possible earthquakes; and design, construct and maintain structures to perform at earthquake in compliance with building codes.
- Environmental engineering is the contemporary term for sanitary engineering, though sanitary engineering traditionally had not included much of the hazardous waste management and environmental remediation work covered by environmental engineering. Public health engineering and environmental health engineering are other terms being used.
- Environmental engineering deals with treatment of chemical, biological, or thermal wastes, purification of water and air, and remediation of contaminated sites after waste disposal or accidental contamination. Among the topics covered by environmental engineering are pollutant transport, water purification, waste water treatment, air pollution, solid waste treatment, and hazardous waste management. Environmental engineers administer pollution reduction, green engineering, and industrial ecology.
- Geotechnical engineering studies rock and soil supporting civil engineering systems. Knowledge from the field of geology, materials science, mechanics, and hydraulics is applied to safely and economically design foundations, retaining, and other structures. Environmental efforts to protect groundwater and safely maintain landfills have spawned a new area of research called geoenvironmental engineering.
- Water resources engineering is concerned with the collection and management of water. As a discipline it therefore combines hydrology, environmental science, meteorology, geology, conservation, and resource. This area of civil engineering relates to the prediction and management of both the quality and the quantity of water in both underground (aquifers) and above ground (lakes, rivers, and streams) resources.
- Hydraulic engineering is concerned with the flow and conveyance of fluids, principally water. This area of civil engineering is intimately related to the design of pipelines, water supply network, drainage facilities (including bridges, dams, channels, culverts, levees, storm sewers), and canals.
- Structural engineering is concerned with the structural design and structural analysis of buildings, bridges, towers, flyovers (overpasses), tunnels, off shore structures like oil and gas fields in the sea, aero structure and other structures. This involves identifying the loads which act upon a structure and the forces and stresses

which arise within that structure due to those loads, and then designing the structure to successfully support and resist those loads.

- Design considerations will include strength, stiffness, and stability of the structure when subjected to loads which may be static, such as furniture or self-weight, or dynamic, such as wind, seismic, crowd or vehicle loads, or transitory, such as temporary construction loads or impact. Other considerations include cost, constructability, safety, aesthetics and sustainability.
- Surveying is the process by which a surveyor measures certain dimensions that generally occur on the surface of the Earth. Surveying equipment, such as levels and theodolites, are used for accurate measurement of angular deviation, horizontal, vertical and slope distances.
- Although surveying is a distinct profession with separate qualifications and licensing arrangements, civil engineers are trained in the basics of surveying and mapping, as well as geographic information systems. Surveyors may also lay out the routes of railways, tramway tracks, highways, roads, pipelines and streets as well as position other infrastructures, such as harbours, before construction.
- Transportation engineering is concerned with moving people and goods efficiently, safely, and in a manner conducive to a vibrant community. This involves specifying, designing, constructing, and maintaining transportation infrastructure which includes streets, canals, highways, rail systems, airports, ports, and mass transit.
- Forensic engineering is the investigation of materials, products, structures or components that fail or do not operate or function as intended, causing personal injury or damage to property. The consequences of failure are dealt with by the law of product liability. The field also deals with retracing processes and procedures leading to accidents in operation of vehicles or machinery.
- Municipal engineering is concerned with municipal infrastructure. This involves specifying, designing, constructing, and maintaining streets, sidewalks, water supply networks, sewers, street lighting, waste management and disposal, storage depots for various bulk materials used for maintenance and public works (salt, sand, etc.), public parks and bicycle paths.
- Control engineering is the branch of civil engineering discipline that applies control theory to design systems with desired behaviors. The practice uses sensors to measure the output performance of the device being controlled and those measurements can be used to give feedback to the input actuators that can make corrections toward desired performance.

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2. Strength of Materials

- Strength of materials, is a subject which deals with the behaviour of solid objects subject to stresses and strains. The complete theory began with the consideration of the behaviour of one and two dimensional members of structures, whose states of stress can be approximated as two dimensional, and was then generalized to three dimensions to develop a more complete theory of the elastic and plastic behaviour of materials. An important founding pioneer in mechanics of materials was Stephen Timoshenko.
- The study of strength of materials often refers to various methods of calculating the stresses and strains in structural members, such as beams, columns, and shafts. The methods employed to predict the response of a structure under loading and its susceptibility to various failure modes takes into account the properties of the materials such as its yield strength, ultimate strength, Young's modulus, and Poisson's ratio.
- Yield strength its the lowest stress that produces a permanent deformation in a material. In some materials, like aluminum alloys, the point of yielding is difficult to identify, thus it is usually defined as the stress required to cause 0.2% plastic strain. This is called a 0.2% proof stress.
- Compressive strength is a limit state of compressive stress that leads to failure in a material in the manner of ductile failure (infinite theoretical yield) or brittle failure .
- Tensile strength or ultimate tensile strength is a limit state of tensile stress that leads to tensile failure in the manner of ductile failure or brittle failure. Tensile strength can be quoted as either true stress or engineering stress, but engineering stress is the most commonly used.
- Fatigue strength is a measure of the strength of a material or a component under cyclic loading, and is usually more difficult to assess than the static strength measures. Fatigue strength is quoted as stress amplitude or stress range . Usually at zero mean stress, along with the number of cycles to failure under that condition of stress.
- Impact strength, is the capability of the material to withstand a suddenly applied load and is expressed in terms of energy. Often measured with the Izod impact strength test or Harpy impact test, both of which measure the impact energy required to fracture a sample. Volume, modulus of elasticity, distribution of forces, and yield strength affect the impact strength of a material.
- A material's strength is dependent on its microstructure. The engineering processes to which a material is subjected can alter this microstructure. The variety of strengthening mechanisms that alter the strength of a material includes work hardening, solid solution strengthening, precipitation hardening and grain boundary strengthening and can be quantitatively and qualitatively explained.
- Strengthening mechanisms are accompanied by the caveat that some other mechanical properties of the material may degenerate in an attempt to make the material stronger.
- In general, the yield strength of a material is an adequate indicator of the material's mechanical strength. Considered in tandem with the fact that the yield strength is the parameter that predicts plastic deformation in the material, one can make informed decisions on how to increase the strength of a material depending its micro structural properties and the desired end effect.
- Strength is expressed in terms of the limiting values of the compressive stress, tensile stress, and shear stresses that would cause failure. The effects of dynamic loading are probably the most important practical consideration of the strength of materials, especially the problem of fatigue. Repeated loading often initiates brittle cracks, which grow until failure occurs. The cracks always start at stress concentrations, especially changes in cross-section of the product, near holes and corners at nominal stress levels far lower than those quoted for the strength of the material.

PROPERTIES OF METALS, STRESS AND STRAIN

Important Mechanical Properties

Elasticity: If is the property by virtue of which a material deformed under the load is enabled to return to its original dimension when the load is removed.

- If body regains completely its original shape then it is called perfectly elastic body.
- Elastic limit marks the partial break down of elasticity beyond which removal of load result in a degree of permanent deformation.
- Steel, Aluminum, Copper, may be considered to be perfectly elastic within certain limit.

Plasticity: The characteristics of the material by which undergoes inelastic strain beyond those at the elastic limit is known as plasticity.

- This property is particularly useful in operation of pressing and forging.
- When large deformation occurs in a ductile material loaded in plastic region, the material is said to undergo plastic flow.

Ductility: It is the property which permits a material to be drawn out longitudinally to a reduced section, under the action of tensile force.

- A ductile material must posses a high degree of plasticity and strength.
- Ductile material must have low degree of elasticity. This is useful in wire drawing.

Brittleness: It is lack of ductility. Brittleness implies that it cannot be drawn out by tension to smaller section.

- In brittle material failure take place under load without significant deformation.
- Ordinary Glass is nearly ideal brittle material.
- Cast iron, concrete and ceramic material are brittle material.

Malleability: It is the property of a material which permits the material to be extended in all direction without rupture.

- A malleable material posses a high degree of plasticity, but not necessarily great strength.

Toughness: It is the property of material which enables it to absorb energy without fracture.

- Modulus of toughness

$$U_T = \text{shaded area} = \left(\frac{\sigma u + \sigma y}{2}\right) \in_t$$

- It is desirable in material which is subjected to cyclic or shock loading.
- It is represented by area under stress-strain curve of material upto fracture.
- Bend test used for common comparative test of toughness.

Hardness: It is the ability of a material to resist indentation or surface abrasion.

- Brinnell hardness test is used to check hardness.

$$\text{Brinnell hardness number} = \frac{P}{\frac{\pi D}{2}\left[D - \sqrt{D^2 - d^2}\right]}$$

where, P = Standard load

D = Diameter of steel ball (mm)

d = Diameter of indent (mm)

Strength: This property enables material to resist fracture under load.

- This is most important property from design point of view. Load required to cause fracture, divided by area of test specimen, is termed as ultimate strength.

Creep: Creep is a permanent deformation which is recorded with passage of time at constant loading. It is plastic deformation (permanent and non-recoverable) in nature.

- The temperature at which creep is uncontrollable is called Homologous Temperature.

Fatigue: Due to cyclic or reverse cyclic loading fracture failure may occur if total accumulated strain energy exceeds the toughness. Fatigue causes rough fracture surface even in ductile metals.

Resilience: It is the total elastic strain energy which can be stored in the given volume of metal and can be released after unloading. It is equal to area under load deflection curve within elastic limit.

Stress and strain

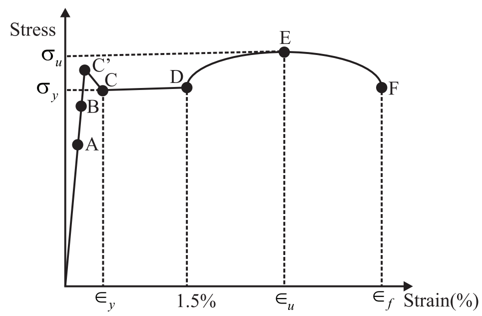
Stress (N/mm^2): It is the resistance offered by the body to deformation

$$\text{Nominal stress (Engineering stress)} = \frac{\text{Load}}{\text{Original Area}}$$

$$\text{Actual/True stress} = \frac{\text{Load}}{\text{Changed (Actual) Area}}$$

Strain: Deformation per unit length in the direction of deformation is known as strain. It is a dimensionless quantity.

Engineering Stress-Strain curve of mild steel for tension under static-loading



C'	-	Upper yield point
D	-	Strain hardening starts
E	-	Ultimate point or maximum stress point
OA	-	Straight line (proportional region, Hooke's law is valid)
OB	-	Elastic region
BC	-	Elastic plastic region
CD	-	Perfectly plastic region
DE	-	Strain hardening
EF	-	Necking region
A	-	Limit of proportionality
B	-	Elastic limit
C	-	Lower yield point
F	-	Fracture point

Limit of Proportionality: It is the stress at which the stress-strain curve ceases to be a straight line.

Hooke's law is valid upto proportional limit.

Elastic Limit: It is the point on the stress-strain curve upto which the materials remains elastic.

- Upto this point there is no permanent deformation after removal of load.

Plastic Range: It is the region of the stress-strain curve between the elastic limit and point of rupture.

Yield Point: This point is just beyond the elastic limit, at which the specimen undergoes an appreciable increase in length without further increase in the load.

Rupture Strength: It is the stress corresponding to the failure point '*F*' of the stress-strain curve.

Proof Stress: It is the stress necessary to cause a permanent extension equal to defined percentage of gauge length.

- Slope of OA = Modulus of elasticity (Young's Modulus)
- It is constant of proportionality which is defined as the intensity of stress that causes unit strain.
- Plastic strain is 10 to 15 times elastic strain.
- Fracture strain $(\in_f)$ depends on percentage carbon in steel. When carbon percentage increases then fracture strain decreases and yield stress increases.
- Failure plane at 90° with longitudinal direction Necking is not formed and failure is due to tension failure. Tensile strength < Shear strength < Compressive strength

Ductile material: If post elastic strain is greater than 5%, it is called ductile material.

- It undergoes large permanent strains before failure, Large reduction in area before fracture e.g. lead, mild steel, copper.

Brittle Material: If post elastic strain is less than 5%. It is called brittle material.

- It fails with only little elongation after the proportional limit is exceeded.
- Very less reduction in area before fracture, e. g Bronze, Rubber, Glass
- **Hooke's Law:** When a material behaves elastically and exhibits a linear relationship between stress and strain, it is called linearly elastic. For such materials stress (σ) is directly proportional to strain $(\in)$.

$$\sigma \propto \in \rightarrow \sigma = E.\in$$

where, σ = Stress

$\in$ = Strain

E = Young modulus of elasticity

$$E_{\text{cast iron}} \approx \frac{1}{2} E_{\text{steel}}$$

$$E_{\text{Aluminium}} \approx \frac{1}{3} E_{\text{steel}}$$

Strain Energy: It is the ability of material to absorb energy when it is strained

$$U = \frac{1}{2} P \times \delta = \frac{1}{2} T \times \theta$$

Here, P = Applied load

δ = Elongation due to applied load

T = Applied torque

θ = Angle of twist due to applied torque

Resilience: Ability of a material to absorb energy in the elastic region when it is strained.

$$= \text{Area under } P - \delta \text{ curve} = \frac{1}{2} P \times \delta$$

Proof Resilience: Maximum energy absorbing capacity of a material in the elastic region is called proof resilience.

$$= \text{Area under } P - \delta \text{ curve} = \frac{1}{2} P_{EL} \times \delta_{EL}$$

Here P_{EL} = Load at elastic limit

δ_{EL} = Elongation upto elastic limit

$$\text{Modulus of Resillience} = \frac{\text{Proof Resillience}}{\text{Volume}} = \frac{\sigma_{EL}^2}{2E}$$

Here σ_{EL} = Strain at elastic limit

E = Modulus of elasticity

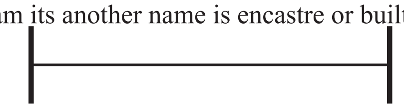
- When bar is free to expand then there will be no thermal stress due to change in temperature.

SHEAR FORCE AND BENDING MOMENT

Types of Beam

Simply Supported Beam: If the ends of a beam are made to rest freely on supports it is called a simply (freely) supported beam.

Fixed Beam: If a beam is fixed at both ends it is called fixed beam its another name is encastre or built-in beam.

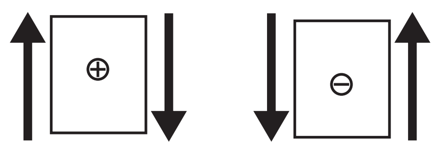


Cantilever Beam: If a beam is fixed at one end while other end is free, it is called cantilever beam.

Continuous Beam: If more than two supports are provided to beam, it is called continuous beam.

Shear Force: It is the internal resistance developed at any section to maintain free body equilibrium of either left or right part of the section.

Sign Convention: Shear force having an upward direction to the left hand side of section or downward direction to the right hand side of section will be taken positive and vice-versa.

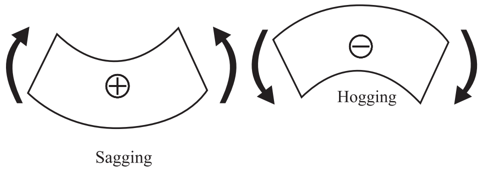


- It may be horizontal or vertical. Shear force at any section is algebraic sum of all transverse forces either from left or right of that section.

Bending Moment: Bending moment at any section is the internal reaction due to all the transverse force either from left side or from right side of that section.

- It is equal to algebraic sum of moments at that section either from left or from right side of that section. Bending moment is different from twisting moment.

Sign convention of Bending moment: A bending moment causing concavity upward will be taken as positive and called sagging bending moment.



A bending moment causing convexity upward will be taken as negative and will be called a hogging bending

Relationship Between Bending Moment (*M*), Shear Force (*S*) an Loading Rate (*w*)

Rate of change of shear force is equal to load

$$\frac{dS}{dx} = w$$

Here, w = Load per unit length

- Negative slope represents downward loading.
- Rate of change of bending moment along the length of beam is equal to shear force.

$$\frac{dM}{dx} = S_x$$

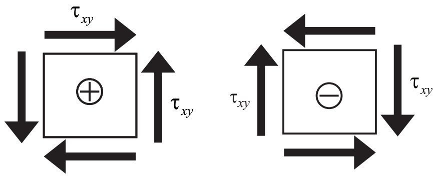
- At hinge, bending moment will be zero.
- Bending moment is maximum or minimum when shear force is zero or changes sign at a section.
- If degree of loading curve = n then degree of shear force curve = $n + 1$ and degree of bending moment curve = $n + 2$.
- Point of contra – flexure/inflexion is that point where bending moment **changes its sign.**

Principal Stress: Principal stress are maximum or minimum normal stress which may be developed on a loaded body.

- The plane of principal stress carry zero shear stress.

Sign Conventions

- ***Tensile*** stress is considered ***positive*** **and** ***compressive*** stress is ***negative.***
- Angle 'θ' is considered **positive** if it is in anti-**clockwise direction.**



Positive shear stress   Negative shear stress

- **Shear** stress acting on a positive face of an element is considered positive if it is acts in positive direction of one of the coordinate axes and negative if acts in the negative direction of the axes. Similarly on a negative face of an element is positive if it act in negative direction of the axes and negative if it act in the positive direction.
- Normally the reference plane taken are major principal plane or vertical plane.
- If θ occupies a position such that $\tau_{(a-a)}$ becomes zero, then such a plane is called principle plane and σ_1 and σ_2 become principle stress.

$$\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

θ_p = Angle of principle plane

- Radius of Mohr circle represent the value of maximum shear stress.
- Normal stress on the plane of maximum shear stress is represented by coordinate of centre of Mohr circle
- Mohr circle reduce to a point in case of hydrostatic loading and zero shear. In case of pure shear, centre will fall at origin.
- Plane stress does not lead to plain strains.
- For strain analysis formulas, put $\frac{\phi_{xy}}{2}$ is place for τ_{xy} every where in stress formulas.
- Max shear stress $= \frac{1}{2}$ (difference of principal stress)
- Max shear strain = difference of principal strains
- *For Shear:* Radius of Mohr circle = τ_{max}
- *For strain:* Radius of Mohr circle $= \frac{\phi_{max}}{2}$

THEORY OF FAILURE

Maximum principal stress theory (Rankings theory): According to this theory, permanent set takes place under a state of complex stress, when the value of maximum principal stress is equal to that of yield point stress as found in a simple tensile test.

- For design criterion, the maximum principal stress (σ_1) must not exceed the working stress 'σ_y' for the material and $\sigma_{1,2} \le \sigma_y$ For no failure.

$$\sigma_{1,2} \le \frac{\sigma_y}{FOS} \text{ For design.}$$

Note: For no shear failure $\tau \le 0.57\sigma_y$

Graphical representation: For brittle material, which do not fail by yielding but fail by brittle fracture, this theory gives satisfactory result.

Maximum principal strain theory (ST. Venant's theory): According to this theory, a ductile material begins to yield when the maximum principal strain reaches the strain at which yielding occurs in simple tension

$$\epsilon_{1,2} \le \frac{\sigma_y}{E} \text{ for no failure in uni-axial loading.}$$

$$\frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E} - \mu\frac{\sigma_3}{E} \le \frac{\sigma_y}{E}$$

For no failure in tri-axial loading.

$$\sigma_1 - \mu\sigma_2 - \mu\sigma_3 \le \left(\frac{\sigma_y}{\text{FOS}}\right) \text{ For design.}$$

Here, $\in$= Principal strain

σ_1, σ_2 and σ_3 = Principal stresses

Maximum shear stress theory (Guest & Tresca's theory): According to this theory, failure of a specimen subjected to any combination of loads when the maximum shearing stress at any point reaches the failure value equal to that developed at the yielding in an axial tensile or compressive test of the same material.

Maximum strain energy theory (Haigh's theory): According to this theory, a body under complex stress fails when the total strain energy on the body is equal to the strain energy at elastic limit in simple tension.

- This theory does not apply to brittle material for which elastic limit stress in tension and in compression are quite different.

Maximum shear strain energy/Distortion energy theory/Mises-Henky theory: It states that inelastic action at any point in a body, under any combination of stress begins, when the strain energy of distortion per unit volume absorbed at the point is equal to the strain energy of distortion absorbed per unit volume at any point in a bar stressed to the elastic limit under the state of uniaxial stress as occurs in a simple tension/compression test.

$$\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right] \le \sigma_y^2$$

For no failure.

$$\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right] \le \left(\frac{\sigma_y}{\text{FOS}}\right)^2$$

For design.

- It can not be applied for material under hydrostatic pressure.
- All theories will give same results if loading is uniaxial.

Deflection of Beams: For design purpose, a beam should be designed in such a way that it has adequate stiffness so that the deflections are within permissible limits.

- Stiffness of beam is inversely proportional to deflection.

Method of determining deflection of Beam

- Double integration method
- Moment area method
- Strain energy method
- Conjugate beam method

Types of Pressure Vessels: Pressure vessels are mainly of two type:

(i) Thin shells: If the thickness of the wall of the shell is less than 1/10 to 1/15 of it diameter, then shell is called thin shells.

$$t < \frac{D_i}{10} \text{ to } \frac{D_i}{15}$$

For thin shell, it is assumed that the normal stresses, which may be either tensile or compressive are uniformly distributed through the thickness of wall.

(ii) Thick Shells: If the thickness of the wall of the shell is greater than 1/10 to 1/15 of its diameter, then shell is called thick shells.

$$t > \frac{D_i}{10} \text{ to } \frac{D_i}{15}$$

- Nature of stress in thin cylindrical shell subjected to internal pressure
  (i) Hoop stress/circumferential stress will be tensile in nature.
  (ii) Longitudinal stress/axial stress will be tensile in nature.
  (iii) Radial stress will be compressive in nature.
- Radial compressive stress varies from a value at the inner surface equal to pressure 'p' to the atmospheric pressure at the outside surface.
- If internal pressure in thin cylinders is low, the radial stress is negligible compared with axial stress and hoop stress. This radial stress is neglected.

Analysis of thin sphere

- Hoop stress/longitudinal stress $\sigma_L = \sigma_h = \dfrac{pd}{4t}$
- Hoop strain/longitudinal strain

$$\in_L = \in_h = \frac{pd}{4tE}(1-\mu)$$

- Volumetric strain of sphere $\in_v = \dfrac{3pd}{4t\,\text{E}}(1-\mu)$
- Thickness ratio for cylindrical shell (t_c) and sphere (t_s), for same strain in both side.

$$\frac{t_c}{t_s} = \frac{2-\mu}{1-\mu}$$

  Thickness ratio for cylindrical shell (t_c) and sphere (t_s), for same maximum stress in both side.

$$\frac{t_c}{t_s} = 2$$

- Auto frittage is used for prestressing the cylinder.
- Wire winding is done for strengthen thin shell. Compounding is done for thick shell cylinders.

Analysis of Thick Cylinders/Lame's Theorem Lame's Assumption:

(i) Material of shell is homogeneous, isotropic and linear elastic.

(ii) Plane section of cylinder, perpendicular to longitudinal axis remains plane under pressure.

Torsion of Shaft

Torsion: Torsion means twisting of a structural member when it is loaded by couple that produces rotation about longitudinal axis.

- Torsion causes rotation of all the fiber about longitudinal/polar axis.
- Force required for torsion is normal to longitudinal axis having certain eccentricity from centroid.

- If no shear force and no bending moment is present in structure member then it will be a case of pure torsion.
- For pure torsion, shaft is prismatic.
- If torque applied in non-circular section then warping will occur.
- A plane section before twisting remains plane after twisting.

Equation of Torsion

$$\frac{\tau}{r} = \frac{T}{J} = \frac{G.\theta}{L}$$

Here, τ = Shear stress
r = Distance from centre of shaft
D = Diameter of shaft
T = Torque
J = Polar moment of inertia
G = Shear modulus
θ = Angle of twist
L = Length of shaft

- Shear stress should be maximum at extreme fibre of shaft. Angle of twist is maximum at the free end of shaft.

Sign Convention: Sign convention of torque can be explained by right hand thumb rule. A positive torque is that in which there is tightening effect of nut on the bolt. From either side of the cross-section. If torque is applied in the direction of right hand fingers than right hand thumbs direction represents movement of the nut.

- In ductile metals in pure torsion failure is due to shear stress in the direction of τ_{max}. Which is at 90° with the longitudinal axis and failure plane is smooth plane.
- Brittle mettle fails in tension so in brittle mettle failure plane will be a rough helical planed at 45° from longitudinal axis.
- Torque will be same on both shafts.
- Total angular deformation of free end of shaft from the fixed end will be equal to sum of angular deformation of first shaft and angular deformation of second shaft.
- Ratio of strain energy for solid and hollow shaft subjected to same torque if outside diameter of both shaft is equal.

$$\frac{U_{\text{hollow}}}{U_{\text{solid}}} = \frac{D^2 + d^2}{D^2}$$

d = inside diameter of hollow shaft

- Ratio of torque in case of hollow and solid shaft subjected to same maximum shear stress.

STRUT: Structural member subjected to axial compressive load is called strut.

Column: Vertical structural member fixed at both ends and subjected to axial compressive load is called column.

Buckling Failure: Euler's Theory

- Assumptions in Euler's Theory
  (i) Axis of column is perfectly straight when unloaded.
  (ii) Load passes through axis
  (iii) Stress in structure are within elastic limit.
  (iv) Flexural rigidity is constant.
  (v) Material is isotropic, homogeneous and linear elastic.
  (vi) Column is long and prismatic and it fails only in buckling.

Limitation of Euler's Formula

(i) There is always crookedness in the column and the load may not be exactly axial.
(ii) This formula does not take into account the axial stress and the buckling load given by this formula may be much more than the actual buckling load.

$$P_e = \frac{\pi^2 EI_{\min}}{l_e^2}$$

P_e = Buckling load
$I_{\min}$ = Min. Moment of inertia about centroidal axis
l_e = Effective length

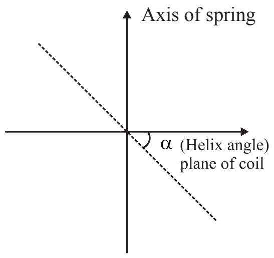
- It is applicable for long column. Effect of crushing is neglected.

Slenderness Ratio (λ): Slenderness ratio of a compression member is defined as the ratio of its effective length to least radius of gyration.

- Spring are used to absorb energy and restore it slowly or rapidly.

Type of spring on the basis of helix angle

- If helix angle is less than or equal to 10º then it is called closed coil spring.
- If helix angle is greater than 10° then it is called open coil spring.



- The best form of spring absorbs greatest amount of energy for a given stress.
- Spring stores energy in the form of resilience.
- Stiffness of spring is inversely proportional to number of coils in the spring. Therefore when a spring is cut into two parts its stiffness become double for every individual part.
- Springs are added just like as capacitors in electronics. Both does the same work i.e., absorbs energy.
- Wahl's factor is considered to consider the effect of direct shear stress and curvature effect.
- The average value of modulus of rigidity for steel used for spring equal to 79300 MPa.
- Shot peening, result in raising the fatigue life of spring because it leave the surface in compression.

MULTIPLE CHOICE QUESTIONS

1. When the intensity of pressure is uniform in a flat pivot bearing of radius r, the friction force is assumed to act at:
(a) r (b) $r/2$
(c) $2r/3$ (d) $r/3$

2. Consider a harmonic motion $x = 1.25 \sin(5t - \pi/6)$ cm. match list-I with list-II and select the correct answer using the codes given below the lists:

List-I	List-II
A. Amplitude (cm)	1. $5/2\pi$
B. Frequency (cycle/s)	2. 1.25
C. Phase angle (rad)	3. 1/5
D. Time period (s)	4. $\pi/6$

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	2	3	4	1
(c)	4	3	2	1
(d)	2	1	4	3

3. Which of the following pairs of devices and their functions are correctly matched?
   1. Flywheel … For storing kinetic energy
   2. Governors … For controlling speeds
   3. Lead screw in lathe … For providing feed to the slides
   4. Fixtures … For locating workpiece and guiding tools

   Select the correct answer using the codes given below:
   Codes:
   (a) 1, 3 and 4 (b) 2 and 3
   (c) 1 and 2 (d) 2 and 4

4. Match list-I and list-II and select the correct answer using the codes given below the lists.
(Notations have their usual meanings):

List-I	List-II
A. Law of correct Steering	1. $f = 3(n-1) - 2j$
B. Displacement relation of Hook's joint	2. $x = R\left[(1-\cos\theta) + \dfrac{\sin^2\theta}{2n}\right]$
C. Relation between kinematic pairs and links	3. $\cot\phi - \cot\theta = c/b$
D. Displacement equation of reciprocating engine piston.	4. $\tan\theta = \tan\phi\cos\alpha$

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	1	2	3	4
(c)	3	4	1	2
(d)	3	2	1	4

5. Force required to accelerate a cylindrical body which rolls without slipping on a horizontal plane (mass of cylindrical body is m, radius of the cylindrical surface in contact with plane is r, radius of gyration of body is k and acceleration of the body is a) is:
(a) $m(k^2/r^2+1) \,.\, a$ (b) $(mk^2/r^2) \,.\, a$
(c) $mk^2 \,.\, a$ (d) $(mk^2/r + 1) \,.\, a$

6. Consider the following statements regarding motions in machines:
   1. Tangential acceleration is a function of angular-velocity and the radial acceleration is a function of angular acceleration.
   2. The resultant acceleration of a point A with respect to a point B on a rotating link is perpendicular to AB.
   3. The direction of the relative velocity of a point A with respect to a point B on a rotating link is perpendicular to AB.

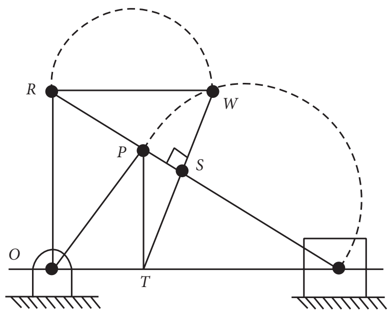
   Which of these statements is/are correct?
   (a) 1 alone (b) 2 and 3
   (c) 1 and 2 (d) 3 alone

7. Consider the following statements:
In petrol engine mechanism, the piston is at its dead centre position when piston
   1. acceleration is zero.
   2. acceleration is maximum.
   3. velocity is zero.
   4. velocity is infinity.

   Which of these statements are correct?
   (a) 1 and 4 (h) 1 and 3
   (c) 2 and 3 (d) 2 and 4

8. The speed of driving shaft of a Hooke's joint of angle 19.5° (given sin 19.5° = 0.33, cos 19.5° = 9.4) is 500 r.p.m. The maximum speed of the driven shaft is nearly:
(a) 168 r.p.m. (b) 444 r.p.m.
(c) 471 r.p.m. (d) 531 r.p.m.

9. The given figure shows the Klein's construction for acceleration of the slider-crank mechanism. Which one of the following quadrilaterals represents the required acceleration diagram?



(a) ORST (b) OPST
(c) ORWT (d) ORPT

10. The spigot of a cotter joint has a diameter of D and carries a slot for cotter. The permissible crushing stress is x times the permissible tensile stress for the material of spigot where $x > 1$.The joint carries an axial load P. Which one of the following equations will give the diameter of the spigot?
(a) $D = 2\sqrt{\frac{P}{\pi\sigma_t}\left[\frac{x-1}{x}\right]}$ (b) $D = 2\sqrt{\frac{P}{\pi\sigma_t}\left[\frac{x+1}{x}\right]}$
(c) $\frac{2}{\pi}\sqrt{\frac{P}{\sigma_t}\left[\frac{x+1}{x}\right]}$ (d) $D = \frac{2P}{\pi\sigma_t}\sqrt{x+1}$
11. The screw and nut in a broaching machine are changed from square thread to Acme thread. The power requirement of the machine at till same r.p.m. will:
(a) remain same
(b) decrease
(c) increase
(d) depend on the operator
12. The creep in a belt drive is due to the:
(a) material of the pulleys
(b) material of the belt
(c) unequal size of the pulleys
(d) unequal tension on tight and slack of the belt
13. The designation 6 × 7 of a wire rope means:
(a) 6 wires
(b) 7 wires
(c) 13 wires
(d) 42 wires
14. A servomotor is connected through a gear ratio of 10 (i.e., motor speed : load side speed = 10 : 1) to a load having moment of inertia J. The equivalent parameter referred to motor shaft side is:
(a) J_{eq}. = 0.01 J (b) J_{eq}. = 10 J
(c) J_{eq}. = 0.1 J (d) J_{eq}. = 100 J
15. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Cam and follower	1. Grubler's rule
B. Screw pair	2. Grashof's linkage
C. 4-bar mechanism	3. Pressure angle
D. Degree of freedom of planar mechanism	4. Single degree of freedom

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	1	2	4	3
(c)	1	4	2	3
(d)	3	2	4	1

16. Consider the following statements:
When two gears are meshing, the clearance is given by the
1. difference between dedendum of one gear and addendum of the mating gear
2. difference between total and the working depth of a gear tooth.
3. distancce between the bottom land of one gear and the top land of the mating gear.
4. difference between the radii of the base circle and the dedendum circle.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 4
17. A body of mass m and radius of gyration k is to be replaced by two masses m_1 and m_2 located at distances h_1 and h_2 from the CG of the original body. An equivalent dynamic system will result, if:
(a) $h_1 + h_2 = k$ (b) $h_1{}^2 + h_2{}^2 = k^2$
(c) $h_1h_2 = k^2$ (d) $\sqrt{h_1h_2} = k^2$
18. Match List-I and List-II and select the correct answer using the codes given below the Lists:

List-I	**List-II**
A. Undercutting	1. Beam strength
B. Addendum	2. Interference
C. Lewis equation	3. Large speed reduction
D. Worm and wheel	4. Intersecting axes
	5. Module

Codes:

	A	B	C	D
(a)	2	5	1	3
(b)	1	5	4	3
(c)	1	3	4	5
(d)	2	3	1	5

19. The natural frequency of transverse vibration of a massless beam of length L having a mass m attached at its midspan is given by:
(EI is the flexural rigidity of the beam)
(a) $\left(\frac{mL^3}{48EI}\right)^{1/2}$ (b) $\left(\frac{48mL^3}{EI}\right)^{1/2}$
(c) $\left(\frac{48EI}{mL^3}\right)^{1/2}$ (d) $\left(\frac{3EI}{mL^3}\right)^{1/2}$
20. A ball-bearing is characterized by basic static capacity = 11000 N and dynamic capacity = 18000 N. This bearing is subjected to equivalent static load = 5500 N. The bearing loading ratio and life in million revolutions respectively are:
(a) 3.27 and 52.0
(b) 3.27 and 35.0
(c) 2.00 and 10.1
(d) 1.60 and 4.1
21. A cantilever of length L, moment of inertia I, Young's modulus E carries a concentrated load W at middle of its length. The slope of cantilever at the free end is:
(a) $\frac{WL^2}{2EI}$ (b) $\frac{WL^2}{2EI}$
(c) $\frac{WL^2}{8EI}$ (d) $\frac{WL^2}{16EI}$

22. In a simple gear train, if the number of idler gears is odd, then the direction of motion of driven gear will:
    (a) be same as that of the driving gear
    (b) be opposite to that of the driving gear
    (c) depend upon the number of teeth on the driving gear
    (d) depend upon the total number of teeth on all gears of the train
23. When a vehicle travels on a rough road whose undulations can be assumed to be sinusoidal, the resonant conditions of the base-excited vibrations, are determined by the:
    (a) mass of the vehicle, stiffness of the suspension spring, speed of the vehicle, wavelength of the roughness curve
    (b) speed of the vehicle only
    (c) speed of the vehicle and the stiffness of the suspension spring
    (d) amplitude of the undulations
24. During torsional vibration of a shaft, the node is characterized by the:
    (a) maximum angular velocity
    (b) maximum angular displacement
    (c) maximum angular acceleration
    (d) zero angular displacement
25. A shaft carries a weight W at the centre. The CG of the weight is displaced by an amount *e* from the axis of rotation. If y is the additional displacement of the CG from the axis of rotation due to the centrifugal force, then the ratio of y to *e* (where ω_c is the critical speed of shaft and ω is the angular speed of shaft) is given by
    (a) $\dfrac{1}{\left[\dfrac{\omega_c}{\omega}\right]^2+1}$
    (b) $\dfrac{1}{\left[\dfrac{\omega_c}{\omega}\right]^2-1}$
    (c) $\left[\dfrac{\omega_c}{\omega}\right]^2+1$
    (d) $\dfrac{\omega}{\left[\dfrac{\omega_c}{\omega}\right]^2-1}$
26. A system has viscous damped output. There is no steady- state lag if input is
    (a) unit step displacement
    (b) step velocity
    (c) harmonic
    (d) step velocity with error-rate damping
27. A motor car has wheel base of 280 cm and the pivot distance of front stub axles is 140 cm. When the outer wheel has turned through 30°, the angle of turn of the inner front wheel for correct steering will be
    (a) 60°
    (b) $\cot^{-1} 2.23$
    (c) $\cot^{-1} 1.23$
    (d) 30°
28. Match List-I (Bearings) with List-II (Applications) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Cylindrical roller	1. Radial loads
B. Ball-bearing	2. Machine needs frequent dismantling and assembling
C. Taper rolling bearing	3. Radial loads with lesser thrust
D. Angular contact	4. Shock loads ball-bearing
	5. Axial expansion of shaft due to rise in temperature

Codes:

	A	B	C	D
(a)	4	3	1	5
(b)	1	3	2	5
(c)	4	1	2	3
(d)	5	4	1	3

29. In a multi-plate clutch with n_0 number of outer discs and n_1 number of inner discs, the number of pairs of active surfaces is
    (a) $n_i + n_0$
    (b) $n_i + n_0 + 1$
    (c) $n_i + n_0 - 1$
    (d) $n_i + n_0 - 2$
30. Match List-I (Properties) with List-II (Units) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Dynamic viscosity	1. Pa
B. Kinematic viscosity	2. m^2/s
C. Torsional stiffness	3. Ns/m^2
D. Modulus of rigidity	4. N m
	5. N/m

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	5	2	4	1
(c)	3	4	2	1
(d)	5	4	2	1

31. A full journal bearing having clearance to radius ratio of 1/100, using a lubricant with $\mu = 28 \times 10^{-3}$ Pa s supports the shaft journal running at N = 2400 r.p.m. If bearing pressure is 1.4 MPa, the Sommerfeld number is:
    (a) 8×10^{-3}
    (b) 8×10^{-5}
    (c) 0.48
    (d) 0.48×10^{-2}
32. In a slider-crank mechanism, the maximum acceleration of slider is obtained when the crank is:
    (a) at the inner dead centre position
    (b) at the outer dead centre position
    (c) exactly midway position between the dead centres
    (d) slightly in advance of the midway position between the two dead centres

33. A sliding contact bearing is operating under unstable condition. The pressure developed in film is p when the journal rotates at N r.p.m. The dynamic viscosity of lubricant is μ and effective coefficient of friction between hearing and journal of diameter D is f. Which one of the following statements is correct for bearing?
    (a) f is directly proportional to μ and p
    (b) f is directly proportional to μ and N
    (c) f is directly proportional to p and D
    (d) f is directly proportional to μ and inversely proportional to N

Directions: The following thirteen (13) items consist of statements, one labelled the 'Assertion (A)' the other labelled the 'Reason (R)'. You are to examine these two statements carefully and decide if the Assertion (A) and the Reason (R) are individually true and if so, whether the Reason is the correct explanation of the Assertion. Select your answer to these items using the codes given below and mark your Answer Sheet accordingly.

Codes:
(a) Both A and R are true and R is the correct-explanation of A
(b) Both A and R are true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true.

34. **Assertion (A):** There is a danger of locomotive wheels being lifted above rails at certain speeds.
    Reason (R): Lifting of the locomotive wheel above rails at certain speed is due to gyroscopic action.
35. **Assertion (A):** A statically and dynamically balanced system of multiple rotors on a shaft can rotate smoothly even at the 'critical speeds' of the system.
    Reason (R): Total balancing eliminates all the 'in plane' and 'out of plane' unbalanced forces of the system.
36. **Assertion (A):** Inertia force always acts through the centroid of the body and is directed opposite to the acceleration of the centroid.
    Reason (R): It has always a tendency to retard the motion.
37. **Assertion (A):** The supply of fuel is automatically regulated by governor according to the engine speed.
    Reason (R): The automatic function is the application of 'd' Alembert's principle.
38. **Assertion (A):** For similar materials having the same maximum permissible tension, V-belt transmits more power than flat belt with same velocity ratio and centre distance.
    Reason (R): As two sides of V-belt are in contact with side faces of pulley groove, larger contact area gives greater effective frictional force.
39. **Assertion (A):** In design of arms of pulley, in belt drive, the cross-section of the arm is elliptical with minor axis placed along the plane of rotation.
    Reason (R): Arms of a pulley in belt drive are subjected to complete reversal of stresses and is designed for bending in the plane of rotation.
40. **Assertion (A):** In a boiler shell with riveted construction the longitudinal seam is jointed by butt joint.
    Reason (R): A butt joint is stronger than a lap joint in a riveted construction.
41. **Assertion (A):** Diamond tools can be used at high speeds.
    Reason (R): Diamond tools have very low coefficient of friction.
42. **Assertion (A):** Hard wheels are chosen for grinding hard metals.
    Reason (R): In hard wheels only the abrasive grains are retained for long time.
43. **Assertion (A):** Buttress thread is a modified square thread profile which is employed on the lead screw of machine tools.
    Reason (R): Frequent engagement and disengagement of lead screw for automatic feed is not possible with perfect square threads, therefore, the square profile has to be modified.
44. **Assertion (A):** No separate feed motion is required during, broaching.
    Reason (R): The broaching machines are generally hydraulically operated.
45. **Assertion (A):** In Dodge Roming sampling tables, the screening inspection of rejected lots is also included.
    Reason (R): Dodge Roming plans are indexed at an LTPD of 10 percent.
46. **Assertion (A):** Time series analysis technique of sales-forecasting can be applied to only medium and short-range forecasting.
    Reason (R): Qualitative information about the market is necessary for long-range forceasting.
47. In production, planning and control, the document which authorizes the start of an operation on the shop floor is the:
    (a) Dispatch order (b) Route plan
    (c) Loading chart (d) Schedule
48. In a study to estimate the idle time of a machine, out of 100 random observations the machine is found idle on 40 observations. The total random observations required for 95% confidence level and ± 5% accuracy are:
    (a) 384 (b) 600
    (c) 2400 (d) 9600
49. Flow process chart contains:
    (a) inspection and operation
    (b) inspection, operation and transportation
    (c) inspection, operation, transportation and delay
    (d) inspection, operation, transportation, delay and storage

50. A new facility has to be designed to do all the welding for 3 products: A, B and C. Per unit welding time for each product is 20 s, 40 s and 50 s respectively. Daily demand forecast for product A is 450, for B is 360 and for C is 240. A welding line can operate efficiently for 220 minutes a day. Number of welding lines required is:
(a) 5 (b) 4
(c) 3 (d) 2

51. Consider the following statements:
Control chart for variables provides the
1. basic variability of the quality-characteristic
2. consistency of performance
3. number of products falling outside the tolerance limits.
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

52. Match List-I (OR-technique) with List II (Model) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Branch and Bound technique	1. PERT and CPM
B. Expected value appraoch	2. Integer programming
C. Smoothing and Levelling	3. Queuing theory
D. Exponential distribution	4. Decision theory

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	2	4	1	3
(c)	3	4	1	2
(d)	3	1	4	2

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

List-I	List-II
A. Decision making under complete certainty	1. Delphi approach
B. Decision making under risk	2. Maximum criterion
C. Decision making under complete uncertainty	3. Transportation model
D. Decision making based on expert opinion	4. Decision tree

Codes:

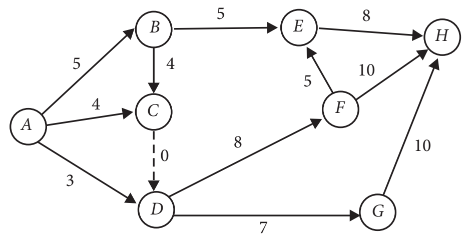
	A	B	C	D
(a)	3	4	1	2
(b)	4	3	2	1
(c)	3	4	2	1
(d)	4	3	1	2

54. During manufacture of cement, the handling of limestone is done by:
(a) belt conveyor
(b) bucket conveyor
(c) overhead crane
(d) fork-lift crane

55. Consider the following statements statements regarding linear programming:
1. Dual of a dual is the primal.
2. When two minimum ratios of the right-hand side to the coefficient in the key column are equal, degeneracy may take place.
3. when an artificial variable leaves the basis, its column can be deleted from the subsequent Simplex tables.
Select the correct answer from the codes given below:
Codes:
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

56. Latest start time of an activity in CPM is the:
(a) latest occurrence time of the successor event minus the duration of the activity.
(b) earliest occurrence time for the predecessor event plus the duration of the activity.
(c) latest occurrence time of the successor event.
(d) earliest occurrence time for the predecessor event.

57. For the network shown in the given figure, the earliest expected completion time of the project is:



(a) 26 days (b) 27 days
(c) 30 days (d) indeterminable

58. Arrivals at a telephone booth are considered to be according to Poisson distribution, with an average time of 10 minutes between one arrival and the next. The length of a phone call is assumed to be distributed exponentially with mean of 3 minutes. The probability that a person arriving at the booth will have to wait, is:
(a) 3/10 (b) 7/10
(c) 7/30 (d) 13/30

59. A thin cylindrical shell is subjected to internal pressure p. The Poisson's ratio of the material of the shell is 0.3. Due to internal pressure, the shell is subjected to circumferential strain and axial strain. The ratio of circumferential strain to axial strain is:
(a) 0.425 (b) 2.25
(c) 0.225 (d) 4.25

60. Which of the following hand-motions belongs to 'Therbligs' in motion study?
1. Unavoidable delay 2. Pre-position
3. Select 4. Reach
Select the correct answer from the codes given below:
Codes:
(a) 1 and 4 (b) 1 and 2
(c) 1, 2 and 3 (d) 2, 3 and 4

61. Which one of the following combinations is valid for product layout?
(a) General purpose machine and skilled labour
(b) General purpose machine and unskilled labour
(c) Special purpose machine and semi-skilled labour
(d) Special purpose machine and skilled labour.

62. Match List-I with List-II and select the correct answer using the codes given below the lists

List-I	**List-II**
A. OC curve	1. Acceptance sampling
B. AOQL	2. Dodge Roming table
C. Binomial distribution	3. *p*-charts
D. Normal curve	4. Control charts for variables

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	1	3	2	4
(c)	4	2	3	1
(d)	4	3	2	1

63. Dispatching function of production, planning and control is:
(a) the dispatch of finished goods on order
(b) the movement of in-process material from shop to shop
(c) authorising a production work order to be launched
(d) the dispatch of bills and invoice to the customers

64. Match List I (Charts) with List-II (Operations informations) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Standard process sheet	1. Operating involing assembly and inspections without machine.
B. Multiple activity chart	2. Operations involiing the combination of men and machines.
C. Right and left hand operation chart	3. Work measurement
D. SIMO chart	4. Basic information for routing
	5. Therbligs

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	1	2	4	5
(c)	1	3	4	2
(d)	4	2	1	5

65. If α is the rake angle of the cutting tool, ϕ is the shear angle and V is the cutting velocity, then the velocity of chip sliding along the shear plane is given by:
(a) $\dfrac{V\cos\alpha}{\cos(\phi-\alpha)}$ (b) $\dfrac{V\sin\alpha}{\cos(\phi-\alpha)}$
(c) $\dfrac{V\cos\alpha}{\sin(\phi-\alpha)}$ (d) $\dfrac{V\sin\alpha}{\sin(\phi-\alpha)}$

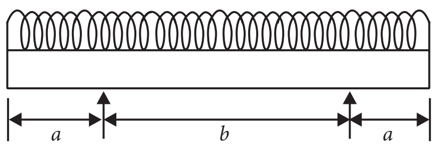
66. Match List I (Cutting Tools) with List II (Applications) and select the correct answer using the codes given below the Lists:

List-I	**List-II**
A. Trepanning tool	1. For surface finishing by honing
B. Side milling cutter	2. For machining gears
C. Hob cutter	3. For cutting keyways in shafts
D. Abrasive sticks	4. For drilling large diameter holes

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	4	3	2	1
(c)	1	2	3	4
(d)	4	2	3	1

67. A horizontal beam is carrying uniformly distributed load supported with equal overhangs as shown in the given figure



The resultant bending moment at the mid-span shall be zero if *a/b* is:
(a) 3/4 (b) 2/3
(c) 1/2 (d) 1/3

68. For cutting of brass with single-point cutting tool on a lathe, tool should have:
(a) negative rake angle (b) positive rake angle
(c) zero rake angle (d) zero side relief angle.

69. Power consumption in metal cutting is mainly due to:
(a) tangential component of the force
(b) longitudinal component of the force
(c) normal component of the force
(d) friction at the metal-tool interface

70. In a shaper machine, the mechanism for tool feed is:
(a) Geneva mechanism
(b) Whitworth mechanism
(c) Ratchet and Pawl mechanism
(d) Ward-Leonard system

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