Youth Competition Times

RRB JE

2nd Stage (CBT-II)

CAPSULE

MECHANICAL & ALLIED ENGINEERING

Theory + MCQ's

Study Material and Question Bank

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INDEX

01. Engineering Mechanics

Introduction-

- Branch of science which deals with the study of action of forces on body is called mechanics.

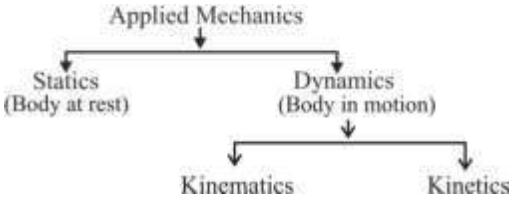
Idealization in Mechanics-

(i) Body is rigid and treated as continuum.

(ii) Support conditions are idealized as simple, hinged, fixed etc.

Continuum-

- When the body is assumed to consist of a continuous distribution of matter is called as continuum.



Units-

Quantity used as the standard measurement is known as unit.

Two types of units are used-

(i) Fundamental unit-

It is independent from any other unit.

Types of fundamental unit-

Quantity	S.I. unit	Symbol
Fundamental unit-		
Length	Meter	m
Mass	Kilogram	Kg
Time	Second	S
Electric current	Ampere	A
Amount of substance	Mole	mol.
Luminous intensity	Candela	Cd
Temperature	Kelvin	K
Supplementary unit-		
Plane angle	Radian	rad
Solid angle	Staradian	sr

(ii) Derived unit-

- It is depended on fundamental units (area, volume, force etc.).

Scalar and vector quantity-

Scalar quantity	A quantity that has magnitude but not particular direction is described as scalar quantity. **Ex.-** Volume, Density, Speed, Energy, Mass and Time.
Vector quantity	A quantity that has magnitude and acts in a direction is called vector quantity. **Ex.-** Displacement, Force, Torque, Linear momentum, Acceleration, Velocity, Magnetic field etc.
Like vectors	Parallel to each other and have same direction but unequal magnitude

Representation of Vector

Tail $\xrightarrow{\text{Vector}}$ Head

Note-

- Vector product $\boxed{\vec{A}\times\vec{B} = AB\sin\theta}$
- Scalar product $\boxed{\vec{A}.\vec{B} = AB\cos\theta}$
- Unit vector $\boxed{\hat{A} = \frac{\vec{A}}{|A|}}$

Systems of units-

(i) Foot - Pound - Second system (FPS)

(ii) Centimeter - Gram - Second system (C.G.S.)

(iii) Meter - kilogram- Second system (M.K.S.)

(iv) International system of units (S.I. units)

Force analysis-

- Any action that tends to maintain or alter the motion of a body or to distort it is termed as force analysis.

Force in defined following four characteristics-

- Line of action
- Direction
- Magnitude
- Point of application

Units of force-

(i) Absolute units-

A unit of measurement that can be defined in terms of mass, length and time is called absolute unit.

(ii) Gravitational units-

This unit is used by engineers for all practical purpose.

- These units depend upon the weight of a body

Gravitational unit of force = g × Absolute unit of force.

Type of Forces According to Nature-

(i) Tension and thrust

Tension is a pulling force that acts along the lengths of medium such as cable or rope.

Thrust is a reactive force that propels an object in a linear action.

(ii) Action and reaction-

An action force is a force that is applied to an object.

A reaction force is a consequence of an action force which is opposite in direction.

(iii) Attraction and repulsion-

It is actually non-contacting forces exerted by one body or another without any visible medium transmission such as magnetic forces.

Newton's laws of motion-

1st law	Body in motion tend to stay in motion and body at rest tend to stay at rest unless acted upon by an unbalanced force. (Laws of inertia)
2nd law	It states that the rate of change of momentum of a body is directly proportional to the impressed force and it takes place in the direction of the force acting on it.
3rd law	For every action there is an equal and opposite reaction.

- 1st Law of motion $\boxed{v = u + at}$
- 2nd Law of motion $\boxed{s = ut + \frac{1}{2}at^2}$
- 3rd Law of motion $\boxed{v^2 = u^2 + 2as}$

Where,
u = Initial velocity, v = Final velocity, s = Distance.

D'Alembert's Principle-

- For a system of mass of particles, the sum of the difference of the force acting on the system and the time derivatives of the moments is zero when projected onto any virtual displacement.

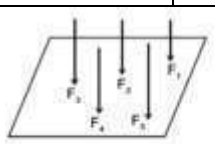
OR

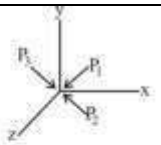
- If a rigid body is acted upon by a system of forces, this system may be reduced to a single resultant force whose magnitude, direction and the line of action may be found out by the methods of graphic statics.

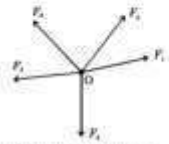
Systems of Forces-

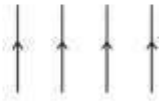
- It is a sum of forces acting on a body in one or more planes.

Force system	Definition
Coplanar forces	The forces, having lines of action lie on the same plane.
Collinear forces	Line of action of forces lie on the same line.
Concurrent forces	When the forces meet at single point or line of action of all forces passes through a single line
Coplanar concurrent forces	Line of action lies in a same plane and meets at a single point to each other.
Coplanar non-concurrent forces	The forces, whose lines of action lie on the same plane but do not meets at a single point.
Non-coplanar concurrent forces	Line of action does not lie on the same plane but meet at a single point.
Non-coplanar non-concurrent forces	The forces, whose lines of action do not lie on the same plane and do not meet at single point.
Non-concurrent forces	Line of action of all forces do not pass through a single point.
Parallel forces	Line of action of all forces are parallel to each other.
(a) Like parallel forces	Line of action of all forces are parallel to each other in same direction.
(b) Unlike parallel forces	Line of action of all forces are parallel to each other in opposite direction.
Non-parallel forces	Line of action of all forces are not parallel each other.


Coplanar Forces


Non-coplanar Concurrent forces


Concurrent Forces


Like parallel forces

Newton's law of gravitation-

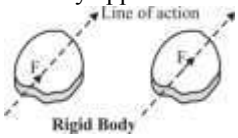
- The force of attraction between any two bodies is directly proportional to their masses and inversely proportional to the square of the distance between them.

$$F = \frac{G.M_1M_2}{d^2}$$

G = Gravitational constant (6.67×10^{-11} $N.m^2/kg^2$)

Principal of Transmissibility of Forces -

- The effect of an external force on a rigid body remains unchanged if that force is replaced by the same magnitude and direction at some other point along its line of action.
- This principal is only applicable for rigid bodies



same magnitude , same line of action and same direction

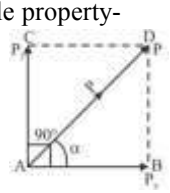
Resultant Force-

- A single force that is equal to sum of all forces in magnitude and opposite in direction acting on a rigid body is called resultant forces.

Mutually perpendicular components-

- When the force component P_y at right angle to P_x then from right angle triangle property-

$P_x = P\cos\alpha$
$P_y = P\sin\alpha$



Analytical Method-

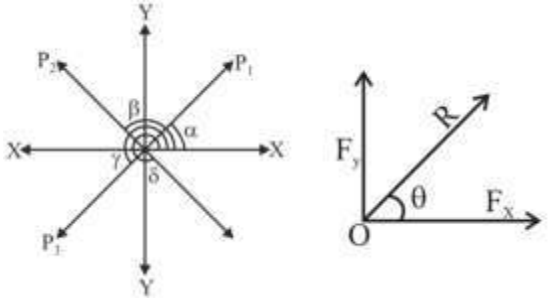
Composition of forces-

- The process of finding out the resultant forces is called composition of forces.

Resolution of forces-

- Process of breaking a force into two components (horizontal and vertical) is called resolution of forces.

Resolution of concurrent coplanar forces-



$$\sum F_x = P_1\cos\alpha + P_2\cos\beta + P_3\cos\gamma + P_4\cos\delta$$

$$\sum F_y = P_1\sin\alpha + P_2\sin\beta + P_3\sin\gamma + P_4\sin\delta$$

Resultant force-

$$R = \sqrt{(\sum F_x)^2 + (\sum F_y)^2}$$

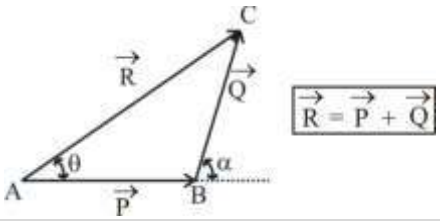
$$\tan\theta = \frac{F_y}{F_x}$$

Sign convention

$\rightarrow \uparrow$	+ ve
$\leftarrow \downarrow$	– ve

Triangle law of force-

- "If two forces acting simultaneously on a body are represented in magnitude and direction by the two sides of triangle taken in order then their resultant may be represented in magnitude and direction by the third side taken in opposite order."



$$\vec{R} = \vec{P} + \vec{Q}$$

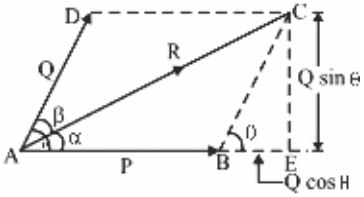
Note

- The rate of change of velocity and the rate of change of momentum of a moving body respectively are– **Acceleration and force**
- The forces in the members cut by the method of section should NOT be– **Concurrent**

Graphical Method-

Parallelogram law of forces -

- "If two coplanar forces, acting simultaneously on a body, be represented in magnitude and direction by the two adjacent sides of a parallelogram then their resultant may be represented in magnitude and direction by the diagonal of the parallelogram which passes through their point of intersection."



- **The magnitude of resultant force R-**

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

- **Direction of resultant force R with the force P-**

$$\tan\alpha = \frac{Q\sin\theta}{P + Q\cos\theta}$$

- **Direction of resultant force R with the force Q-**

$$\tan\beta = \frac{P\sin\theta}{Q + P\cos\theta}$$

When,

θ = 0°	R = P + Q
θ = 90°	$R = \sqrt{P^2 + Q^2}$ If, Q = P, then $R = \sqrt{2}$ P and $\alpha = \frac{\theta}{2}$
θ = 180°	R = P – Q

Polygon law of forces-

- If number of forces acting simultaneously on a particle be represented in magnitude and direction by the sides of the polygon takes in an order, then the resultant of all forces may be represented in magnitude and direction by closing side of polygon in opposite order.

Note-

- Determination of resultant force by vector method is called polygon law of forces.

General Conditions of Equilibrium-

- When number of forces or resultant force acting on a body produce no change in its state of rest or of motion then the body is said to be in equilibrium.

1. Force law of equilibrium-

(i) Algebraic sum of all the horizontal forces is zero, $\sum H = 0$

(ii) Algebraic sum of all the vertical forces is zero, $\sum V = 0$

2. Moment law of equilibrium-

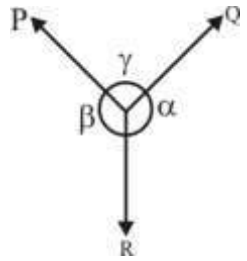
Algebraic sum of all the moments is zero, $\sum M = 0$

Note-

- Resultant of equilibrium forces is zero.
- Equilibrium force brings the body in equilibrium condition.

Lami's Theorem-

- "If three coplanar forces acting at a point in a body which is in equilibrium, then each force is proportional to the sine of the angle between the other two forces."



- When these forces are in equilibrium then, as per Lami's theorem -

$$\frac{P}{\sin\alpha}=\frac{Q}{\sin\beta}=\frac{R}{\sin\gamma}$$

Note-

- Lami's theorem is applicable only for coplanar, concurrent, non-linear and radial forces.
- When applied force on body is in equilibrium then angle formed at joint should be 120º.

Law of Conservation of Energy :

- The energy can neither be created nor destroyed, though it can be transformed from one form into any of the forms, in which the energy can exists.
- When a particle is moving from position 1 to position 2 under the action of only conservative forces (i.e., when frictional force does not exist) then by energy conservation law we say that the total energy remains constant.

$$\text{Total energy} = \frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2 = \text{constant}$$

Law of Conservation of Momentum

- The total momentum of two bodies remains constant after their collision or any other mutual action.

  $(m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2)$

  m = Mass

  u, v = Initial, final velocity

Coefficient of Restitution-

Velocity of separation $(v_2 - v_1)$

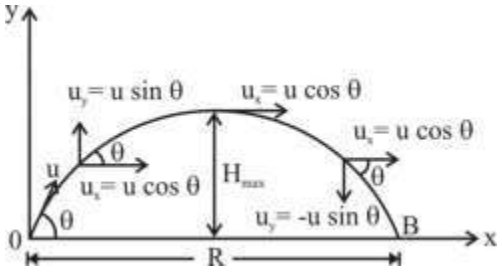
$= e \times$ [velocity of approach $(u_1 - u_2)$]

e = Coefficient of restitution

e = 0 (Bodies are inelastic)

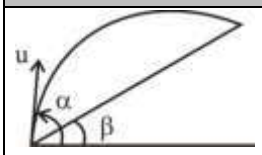
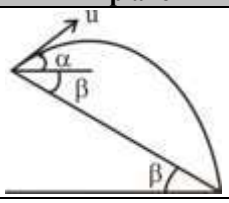
e = 1 (Bodies are perfectly elastic)

Projectile Motion-



$$y = x.\tan\theta - \frac{1}{2}\frac{gx^2}{u^2\cos^2\theta}$$

Height	$h = \frac{u^2\sin^2\theta}{2g}$	$h_{max.} = \frac{u^2}{2g},\ (\theta = 90°)$
Time period	$T = \frac{2u\sin\theta}{g}$	$T_{max.} = \frac{2u}{g},\ (\theta = 90°)$
Range	$R = \frac{u^2\sin 2\theta}{g}$	$R_{max.} = \frac{u^2}{g},\ (\theta = 45°)$

Body projected upward to inclined plane	**Body projected downward to inclined plane**
	
• $T = \frac{2u}{g\cos\beta}[\sin(\alpha-\beta)]$	• $T = \frac{2u}{g\cos\beta}[\sin(\alpha+\beta)]$
• $R = \frac{u^2}{g\cos^2\beta}$ $[\sin(2\alpha - \beta) - \sin\beta]$	• $R = \frac{u^2}{g\cos\beta}$ $[\sin(2\alpha + \beta) + \sin\beta]$
• Condition for maximum range- $\alpha = 45° + \frac{\beta}{2}$	• For maximum range- $\alpha = 45° - \frac{\beta}{2}$

NOTE-

Rectilinear/Translation motion-

- The motion of a body in a straight line is known as rectilinear motion.

Moments-

- Rotational tendency of a force about of fixed point is called moment.

  Moment, $\boxed{M = \text{Force} \times \text{Perpendicular distance of force from fixed point}}$

Unit- N-m

Varignon's theorem-

- "The algebraic sum of the moment of a resultant of two forces, about a point lying in the plane of the forces, is equal to the algebraic sum of moments of these two forces about the same point."

  The force system may be either coplanar or spatial, but it must be concurrent.

$$\sum M_{Forces} = M_{Resultant}$$

- Principle of moments is the extension of varignon's theorem.

Couple -

- It is a pair of two equal and opposite forces acting on a body in a such way that the lines of action of the two forces are not in the same straight line.

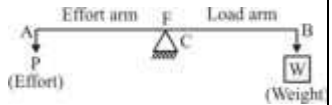
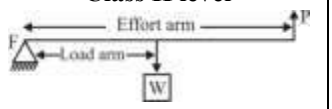
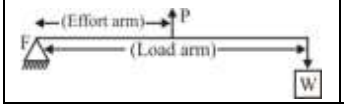
OR

- "The moment of a couple is known as torque which is equal to one of the forces forming the couple multiplied by arm of the couple."
  Ex.-Twisting a screw driver, Turning the cap, Opening or closing a water tap

Lever-

- It is consisting of a beam or rigid rod pivoted at a fixed hinge, or fulcrum about which it can rotate.
- "It works on the principle of moments."

Class of lever-

Class I lever 	**Ex. -** A pair of Scissors, Crowbar, Beam balance, Hand pump. ➢ Mechanical Advantage, M.A. ≥ 1, MA < 1.
Class II lever 	**Ex.-** Nut-crackers, Wheel barrow, Paper sheet cutter, Bottle openers, Weight lifting rod ➢ M.A. > 1 (Always)
Class III lever 	**Ex.-**Fishing rod, Tongs, Human forearm, Forceps, Shovel, Knife ➢ M.A. < 1 (Always)

Mechanical Advantage (M.A.)-

$$M.A. = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{\text{Load}}{\text{Effort}} = \frac{W}{P}$$

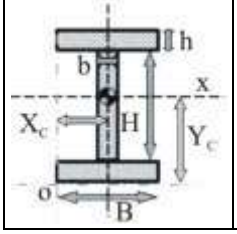
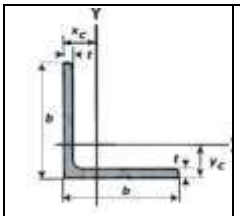
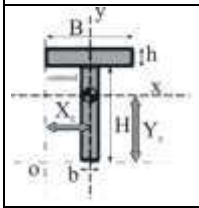
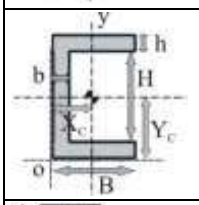
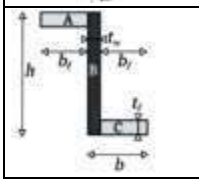
Radius of gyration- Radius of gyration can be defined as the imaginary distance from the centroid at which the area of cross section is imagined to be focused at a point in order to obtain the same moment of inertia. It is denoted by K.

$I = mK^2$

1. In mass moment of inertia, $K = \sqrt{\frac{I_m}{m}}$
2. In area moment of inertia, $I = AK^2$ or $K = \sqrt{\frac{I}{A}}$

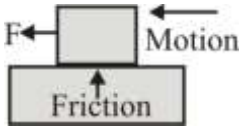
Where, I_m = Mass moment of inertia or minimum moment of inertia, m = Mass of body.

Moment of Inertia of compound standard section-

Standard Section	Formula
	$I_{xx}=H^3b/12+2[h^3B/12+hB(h+H)^2/4]$ $I_{yy}=b^3H/12 + 2(B^3h/12)$
	$I_x = 1/3\times[b^4-(b-t)\times(b-t)^3]-A\times(b-y_c)^2$ $I_y=1/3\times[b^4-(b-t)\times(b-t)^3]-A\times(b-x_c)^2$ Where, A = Area
	$I_{xx} = bH(y_{cog} - H/2)^2 + bH^3/12 + hB(H + h/2 - y_{cog})^2 + h^3B/12$ $I_{yy} = b^3H/12+B^3h/12$
	$I_{xx}=H^3b/12+2[h^3B/12+hB(h+H)^2/4]$ $Iyy = b^3H/12 + bH(x_{cog} - b/2)^2 + 2B^3h/12 + 2Bh(x_{cog} - B/2)^2$
	$I_x = \frac{b_f t_f (h-t_f)^2}{2} + \frac{b_f t_f^3}{6} + \frac{t_w h^3}{12}$ $I_y = \frac{b_f t_f (b_f + t_w)^2}{2} + \frac{t_f b_f^3}{6} + \frac{h t_w^3}{12}$

Friction-

Friction is a force resisting relative motion between two surface.



(i) Friction acts parallel to the surface of contact.
(ii) Friction depends upon the nature roughness of the surface contact and material also.

Frictional Force-

- When, a body moves relative to an other, a tangential force always developed along the surface of contact. These tangential forces is called frictional force.
  Friction force is directly proportion to the normal reaction i.e.
  $f \propto R$
  $f = \mu.R$

Where,
f = Frictional force
R = Reaction force
μ = Friction factor or co-efficient of friction

Co-efficient of friction (μ)

- The Ratio of limiting friction (f_{max}) and normal reaction (R) is known as co-efficient of friction.
- For fully smooth surface, $\mu = 0$
  There is two types of co-efficient of friction.

(i) Static co-efficient of friction (max. friction)-

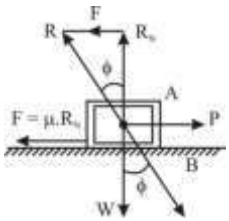
$$\mu_S = \frac{f_s}{R}$$

(ii) Kinetic co-efficient of friction-

$\boxed{\mu_k = \frac{f_k}{R}}$ Note- $\boxed{\mu_s > \mu_k}$

Limiting Angle of friction -

- Angle between normal reaction R and resultant force is called angle of friction. It is also called limiting angle of friction



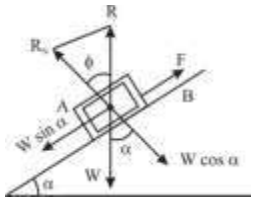
$\tan \phi = F/R_N = \mu R_N/R_N = \mu$

$\tan \phi = \mu$

Static co-efficient of friction is equal to the tangent of friction angle.

Angle of repose(ϕ)-

- Minimum angle of a inclined plane with the horizontal on which a body can slip is called angle of repose.



$W \sin \alpha = F\ \mu.R_N = \mu.W \cos \alpha$

$\tan \alpha = \mu = \tan \phi$ or $\alpha = \phi$

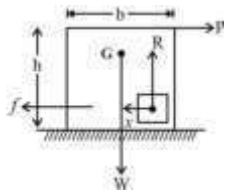
- Angle of repose = Angle of friction

Types of Friction-

Static Friction	The frictional force which prevents one body from sliding on another is known as static friction.
Limiting friction	The max. friction force, when a body just begins to slide over the another surface of body is called limiting friction. • At this condition the body just start moving
Dynamic friction	It is defined as the friction that occurs between any two surfaces when they are in a moving position. It is also called kinetic friction.
Rolling friction	The friction resisting the motion of a rolling body on another surface is known as rolling friction.

Condition for sliding and rolling -

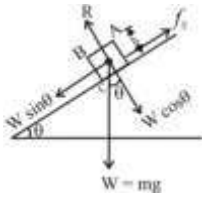
(i) At rough horizontal surface-



Sliding condition- $\boxed{\mu < \frac{b}{2h}}$

Rolling condition- $\boxed{\mu > \frac{b}{2h}}$

(ii) At Inclined rough surface-



At equilibrium condition-

$\boxed{f = W \sin \theta}$

$R = W \cos \theta$

Sliding condition-

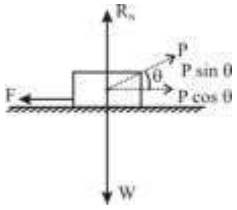
$\boxed{\tan \theta = \mu < \frac{b}{h}}$

Rolling condition-

$\boxed{\tan \theta = \mu > \frac{b}{h}}$

Resolution of Force considering Friction-

- Rough Horizontal:



$$P = \frac{W \sin \phi}{\cos(\theta - \phi)}$$

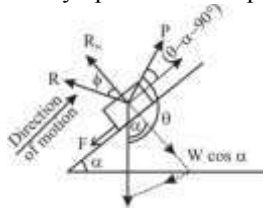
$(\mu = \tan \phi)$

$P \rightarrow \min$

$(\theta = \phi)$

$\boxed{P_{min} = W \sin \theta}$

- Motion of the body up the inclined plane-



$$P = \frac{W \sin(\alpha + \phi)}{\sin[\theta - (\alpha + \phi)]} \qquad (\mu = \tan \phi)$$

(i) When the effort applied horizontal, $(\theta = 90°)$

$$P = \frac{W \sin(\alpha + \phi)}{\cos(\alpha + \phi)} = W \tan(\alpha + \phi)$$

(ii) When the effort applied is parallel to the plane, $(\theta = 90 + \phi)$

$P = (\sin \alpha + \mu \cos \alpha)$

RRB Previous Years Questions

1. A force is completely defined when we specify

(a) magnitude (b) direction

(c) point of application (d) all of the above

RRB JE 14-12-2014 (02 Red Paper)

Ans. (d) : A force may be defined as an agent which produces or tends to produce, destroy or tends to destroy the motion of body.

- In order to completely defined the force, we must know the following characteristics of a forces.

1. Magnitude of the force
2. The line of action (direction) of the force
3. Point of application
4. The nature of the force i.e. push or pull

2. If the resultant R, of two forces P and Q acting at an angle θ makes an angle α with P, then

(a) $\tan\alpha = P\sin\theta / (Q - P\sin\theta)$

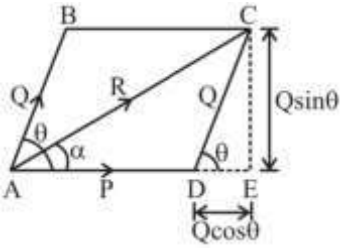
(b) $\tan\alpha = Q\sin\theta / (P + Q\cos\theta)$

(c) $\tan\alpha = P\sin\theta / (P + Q\sin\theta)$

(d) $\tan\alpha = P\cos\theta / (P + Q\sin\theta)$

RRB-JE 30.08.2019, Ist Shift

Ans. (b) :



According to law of parallelogram.

In ΔAEC, $\tan\alpha = \frac{CE}{AE}$

$$\tan\alpha = \frac{CE}{AD + DE}$$

$$\boxed{\tan\alpha = \frac{Q\sin\theta}{P + Q\cos\theta}}$$

3. According to Lami's theorem :

(a) the three forces must be equal

(b) the three forces must be at 120^0 to each other

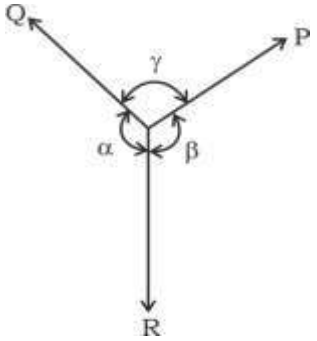
(c) the three forces must be in equilibrium

(d) if the three forces acting at a point are in equilibrium, then each force is proportional to the sine of the angle between the other two

RRB JE CBT-II 31.08.2019 IInd Shift

Ans. (d) : According to Lami's theorem, if the three forces acting at a point are in equilibrium, then each force is proportional to the sine of the angle between the other two.

$$\boxed{\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}}$$



Where, P, Q and R are the three forces and α,β & γ are the angles.

4. The resultant of two forces P and Q acting at an angle θ is

(a) $\sqrt{P^2 + Q^2 + 2PQ\sin\theta}$

(b) $\sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

(c) $\sqrt{P^2 + Q^2 - 2PQ\cos\theta}$

(d) $\sqrt{P^2 + Q^2 - 2PQ\sin\theta}$

RRB JE 14-12-2014 (01 Red Paper)

Ans : (b) The resultant of two forces P and Q acting at angle θ. Then,

Resultant, $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

[from Parallelogram's Law]

Special Condition–

(i) If $\theta = 0°$ then $\cos\theta = \cos0° = 1$

$$R = \sqrt{P^2 + Q^2 + 2PQ}$$

$$\boxed{R = P + Q}$$

If θ = 0, then its value will be maximum.

(ii) If $\theta = 180°$, then $\cos\theta = \cos180 = -1$

$$R = \sqrt{P^2 + Q^2 + 2PQ \times (-1)}$$

$$\boxed{R = P - Q} \qquad [P > Q]$$

If $\theta = 180°$, then its value will be minimum.

5. The forces whose line of action lie along the same line are known as:

(a) collinear forces

(b) coplanar parallel forces

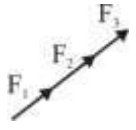
(c) coplanar non-concurrent forces

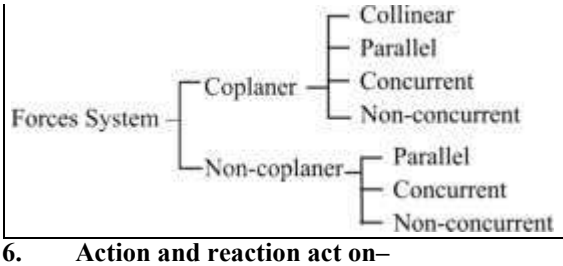
(d) coplanar concurrent forces

RRB-JE 29.08.2019, Ist Shift

Ans. (a) : The forces whose line of action lie along the same line are known as collinear forces.

Forces F_1, F_2, F_3 and F_4 are collinear because they lie on the same line of action.



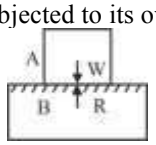


6. Action and reaction act on–

(a) Different bodies but in same direction
(b) Same body but in opposite direction
(c) Same body and in same direction
(d) Different bodies but in opposite direction

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (d) Action and reaction act on different bodies but in opposite direction.
From fig, Body A subjected to its own weight (W) in



form of action and body B oppose this action in the opposite direction (R) in the form of reaction.
& $\boxed{R = W}$ (But opposite in direction)

7. The horizontal component of tensile force in a wire that makes 60^o with horizontal and is carrying a force of 20 kN is-

(a) 30 kN (b) 18 kN
(c) 10 kN (d) 25 kN

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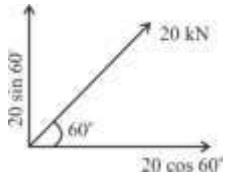
Ans : (c)



$\sum H = 0$
Component $(F_H) = 20 \cos 60^o$

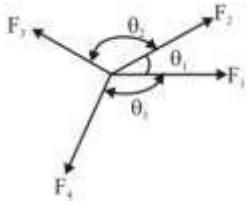
$$= 20 \times \frac{1}{2} = 10 kN$$

8. The algebraic sum of the resolved parts of a number of forces in a given direction is equal to the resolved part of their resultant in the same direction. This is known as-

(a) Principle of resolution of forces
(b) All of the options
(c) Principle of transmissibility of forces
(d) Principle of independence of forces

RRB-JE 29.08.2019, Ist Shift

Ans. (a) : According to the principle of resolution of forces the algebraic sum of the resolved parts of a number of forces in a given direction is equal to the resolve part of their resultant in the same direction.



$$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$$

$$\tan\theta = \frac{\Sigma F_y}{\Sigma F_x}$$

9. Which one of the following is not a scalar quantity?

(a) Volume (b) Mass
(c) Force (d) Length

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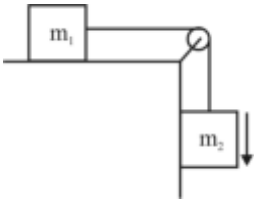
Ans. (c) : Generally, there are two type of physical quantity–
1. Scalar quantity 2. Vector quantity
Scalar quantity–When a quantity needs only magnitude to define it, then it is called scalar quantity.
Ex.: mass, density, volume, pressure, temperature, length etc.
Vector quantity–When a quantity needs both magnitude and direction to define it, then it is called vector quantity.
Ex. : acceleration, force, velocity

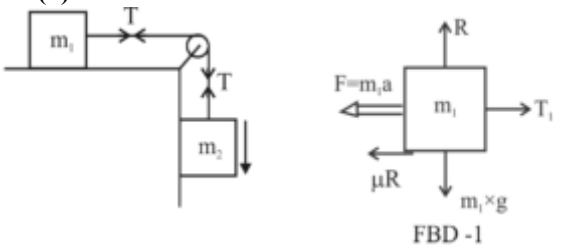
10. In the figure below, what is the acceleration of body with mass m_2, given g is the acceleration due to gravity (assume pulley and surfaces are smooth)



(a) g (b) $\frac{m_1 + m_2}{m_1}$
(c) $\frac{m_1 + m_2}{m_2} g$ (d) $\frac{m_2}{m_1 + m_2} g$

RRB JE 14-12-2014 (03 Green Paper)

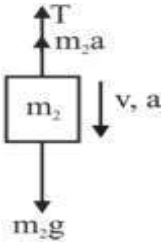
Ans. (d) :



FBD -1

For mass m_1–

$T = m_1 a + \mu R$ ($\mu = 0$ due to smooth surface)
$T = m_1 a$ ..... (i)



For mass m_2 –

$m_2g - T = m_2a$ ..... (ii)

From equation (i) and equation (ii)

$m_2g - m_1a = m_2a$

$m_2g = (m_1 + m_2)a$

$$\boxed{a = \frac{m_2 g}{m_1 + m_2}}$$

11. According to the principle of moments-

(a) If a system of coplanar forces is in equilibrium, then their algebraic sum is zero

(b) Positive and negative couples can be balanced

(c) If a system of coplanar forces is in equilibrium, then the algebraic sum of their moments about any point in their plane is zero

(d) The algebraic sum of the moments of any two forces about any point is equal to the moment of the resultant about the same point

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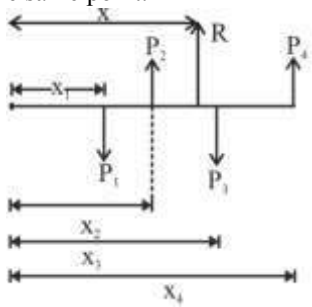
RRB-JE 29.08.2019, Ist Shift

Ans. (d) : According to the law of moments, if a number of coplanar forces acting on a particle are in equilibrium, then the algebraic sum of their moments about any point is equal to the moment of resultant force about the same point.



$$R \times x = P_1x_1 - P_2x_2 + P_3x_3 - P_4x_4$$

12. A couple produces

(a) Translatory motion

(b) Rotational motion

(c) Combined translatory and rotational motion

(d) None of these

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Ans. (b) : A couple consists of two equal and opposite forces acting at a separation, so that net force becomes zero. When a couple acts on a body it rotates the body but does not produce any translatory motion. Hence, only rotational motion is produced.

13. The distance between the forces acting in the couple is–

(a) Always a fixed distance

(b) A finite variable distance

(c) Zero

(d) Infinity

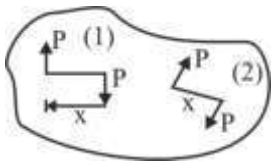
RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (b) The two equal and opposite forces, whose lines of action are different, form a couple.

Couple = Px

- The distance between the forces acting in the couple is a finite variable distance.

i.e. (1) = (2)



14. If no external torque acts on a rigid body, then the product of its moment of inertia and the angular velocity about the axis of rotation must remain constant is the statement of-

(a) Law of parallelogram forces

(b) Law of polygon of forces

(c) Law of triangular forces

(d) Law of Conservation of Angular Momentum

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Ans. (d) : If no external torque acts on a rigid body then the product of its moment of inertia and the angular velocity about the axis of rotation must remain constant.

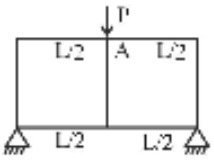
• Principle of conservation of angular momentum-

$L = \text{Constant}$

or $I\omega = \text{constant}$

$$\boxed{I_1\omega_1 = I_2\omega_2}$$

15. What is the moment at A for a frame shown below :



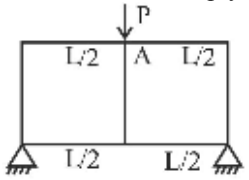
Each vertical member has very large Moment of inertia

(a) $\frac{PL}{2}$ (b) $\frac{PL}{4}$

(c) $\frac{PL}{8}$ (d) $\frac{PL}{16}$

RRB JE 21-12-2014 (09 Yellow Paper)

Ans : (b) Because, moment of inertia of all component of frame is more. It is work as a simply supported beam.



By Symmetricity, $R_A = \frac{P}{2}$, and $R_B = \frac{P}{2}$

Moment at point A, $\left[M = \frac{PL}{4}\right]$

16. Limiting force of friction is the :

(a) tangent of angle between normal-reaction and the resultant of normal reaction and limiting friction

(b) ratio of limiting friction and normal reaction

(c) the friction force acting when the body is just about to move
(d) the friction force acting when the body is in motion

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Ans. (c) :
- The maximum valve of frictional force, which comes into play, when a body just begins to slide over the surface of the other body, is known as limiting force of friction.
- The friction, experienced by a body, when in motion, is called dynamic friction. It is also called kinetic friction. It is of the following two types.

a - Sliding friction
b- Rolling friction

17. The minimum angle made by an inclined plane with the horizontal such that an object placed on the inclined surface just begins to slide is called-
(a) Angle of elevation (b) Angle of friction
(c) Angle of Repose (d) Angle of latitude

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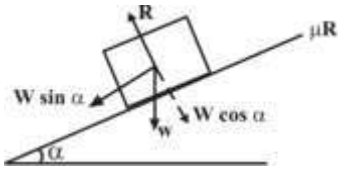
Ans. (c) : The minimum angle made by an inclined plane with the horizontal such that an object placed on the inclined surface jus begins to slide is called angle of repose.



$W\cos\alpha = R$ --------(i)
$W\sin\alpha = \mu R$ ------(ii)
by equation (i) & (ii)
$W\sin\alpha = \mu W\cos\alpha$
$\tan\alpha = \mu = \tan\alpha$
$\boxed{\alpha = \theta}$
Where, α = Angle of repose, θ = friction angle

18. A block weighing W = 20 kN is resting on an inclined plane which makes and angle of 30º to the horizontal. The component of gravity force parallel to inclined plane is-
(a) 17.32 kN (b) 10 kN
(c) 5 kN (d) 14.14 kN

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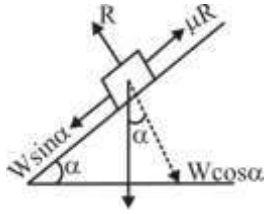
Ans. (b) : Given , W = 20 kN
$\alpha = 30^\circ$



The component of gravity force parallel to inclined plane (F) = W sinα
$= 20 \times \sin 30^\circ = 10\text{kN}$

19. Coulomb friction is the friction between-
(a) Solids and liquids
(b) Two lubricated surfaces
(c) Bodies having relative motion
(d) Two dry surfaces

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Ans. (d) : Coulomb friction model is used for modeling tangential forces between contact surfaces. For one - dimensional problem, if the tangential forces are lower than friction forces (μR), they will be proportional to the relative displacement between the contact surfaces.

20. Which of the following is INCORRECT in the laws of dry friction?
(a) The frictional force always acts in a direction opposite to that in which the body tends to move
(b) The force of friction is dependent of the area of contact between the two surfaces
(c) The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two contacting surfaces
(d) The force of friction depends upon the roughness/smoothness of the surfaces

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Ans. (b) : According to laws of dry Friction :-
(i) The frictional force always acts in a direction opposite to that in which the body tends to move.
(ii) The force of friction is independent of the area of contact between the two surfaces.
(iii) The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two contacting surfaces.

i.e, $\boxed{\mu = \frac{F}{R}}$

(iv) The force of friction depends upon the roughness smoothness of the surfaces.

21. The angle between the resultant reaction and normal to the plane on which the motion of body is impending is known as–
(a) Angle of limiting friction
(b) Angle of repose
(c) Angle of friction
(d) Angle of zenith

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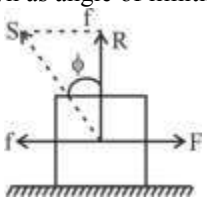
Ans : (a) The angle betwen the resultant reaction and normal to the plane on which the motion of body is impending is known as angle of limiting friction.



In fig. ϕ = Angle between R and S
$\boxed{S = \sqrt{f^2 + R^2}}$
Where,
S = Resultant force of friction and normal reaction
R = Normal reaction
F = Friction force

22. If 'W' is weight of a body, 'α' is angle of an inclined plane and 'ϕ' is angle of friction, then the force required to drag the body when it is just impending to move up the plane, is–

(a) W sin (α + ϕ) (b) W tan (α + ϕ)

(c) W sec (α + ϕ) (d) W cos (α + ϕ)

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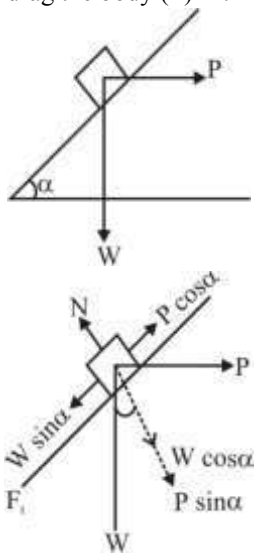
Ans. (b) : Given that, W = Weight of body

α = Inclination angle of plane

ϕ = Friction angle

Fore required to drag the body (P) = ?



From FBD of the figure

$\Sigma F_x = 0$

$P\times\sin\alpha + W\times\cos\alpha = N$

$\Sigma F_y = 0$

$W\times\sin\alpha + \mu N = P\times\cos\alpha$

$W\times\sin\alpha + \mu(P\times\sin\alpha + W\times\cos\alpha) = P\times\cos\alpha$

$W\times\sin\alpha + \mu W\cos\alpha = P\times\cos\alpha - \mu P\sin\alpha$

$$P = \frac{W(\sin\alpha + \mu\cos\alpha)}{(\cos\alpha - \mu\sin\alpha)}$$

$$P = \frac{W(\tan\alpha + \mu)}{(1 - \mu\tan\alpha)} \qquad (\mu = \tan\phi)$$

$$P = \frac{W(\tan\alpha + \tan\phi)}{(1 - \tan\phi\times\tan\alpha)} \Rightarrow P = W\tan(\alpha+\phi)$$

23. Moment of inertia of a circular section is :

(a) $\frac{\pi d^4}{64}$ b) $\frac{\pi d^4}{16}$

(c) $\frac{\pi d^3}{64}$ (d) None of these

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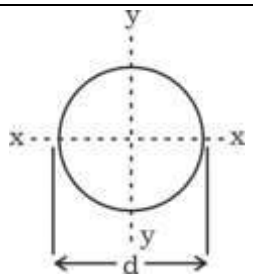
Ans. (a) :

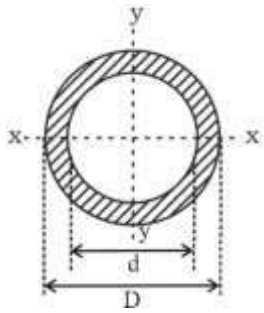
- The moment of inertia of a circular section of diameter, 'd'.

$$I_{xx} = I_{yy} = \frac{\pi d^4}{64}$$



- the moment of inertia of a hollow circular section of outer diameter D and inner diameter d,

$$I_{xx} = I_{yy} = \frac{\pi}{64}\left(D^4 - d^4\right)$$



24. Mass moment of inertia has unit of _____

(a) kg-m^2 (b) kg-m^4

(c) kg/m^2 (d) kg/m^4

RRB JE CBT-II 31.08.2019 IInd Shift

Ans. (a) : Mass moment of inertia is the second moment of mass of the body.

and $I = mk^2$ kg-m^2

- Area moment of inertia has unit of m^4 or mm^4.

25. Moment of Inertia of a rectangular section having width (b) and depth (d) about an axis passing through its CG and parallel to the depth (d) is

(a) $\frac{db^3}{12}$ (b) $\frac{db^3}{18}$

(c) $\frac{db^3}{6}$ (d) $\frac{db^3}{36}$

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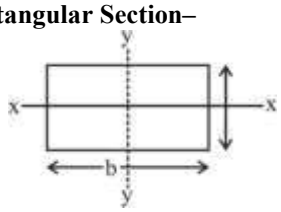
Ans. (a) : Rectangular Section–



- Moment of inertia–

$$I_{yy} = \frac{db^3}{12}$$

- An axis passing through its C.G. and parallel to the width (b). Than moment of inertia–

$$I_{xx} = \frac{bd^3}{12}$$

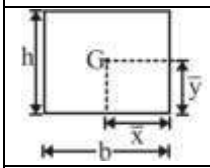
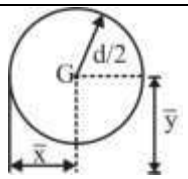
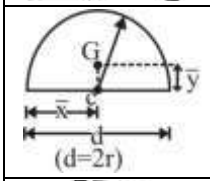
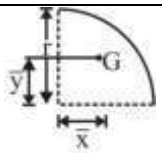
26. The center of gravity of a semi-circle lies at a distance of ..... from its base measured along the vertical radius.

(a) $3r/4\pi$ (b) $8r/3\pi$

(c) $4r/3\pi$ (d) $3r/8\pi$

RRB-JE 29.08.2019, Ist Shift

Ans. (c) : The center of gravity of a semi-circle lies at a distance of $4r/3\pi$ from its base measured along the vertical radius

Different section	$\bar{y}$	$\bar{x}$
	$\frac{h}{2}$	$\frac{b}{2}$
	$\frac{d}{2}$	$\frac{d}{2}$
	$\frac{4r}{3\pi}$	$\frac{d}{2}$
	$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$

27. The moment of inertia of a rectangular section 3 cm wide and 4 cm deep about X-X axis passing through centre is-

(a) 9 cm^4 (b) 12 cm^4

(c) 16 cm^4 (d) 20 cm^4

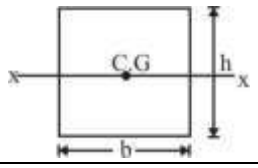
RRB-JE 29.08.2019, Ist Shift

Ans. (c) : Given, b = 3m, h = 4cm

Moment of inertia about X - X

$$I_{xx} = \frac{bh^3}{12}$$

$$= \frac{3\times 4^3}{12} = 16cm^4$$



28. The moment of inertia of semicircular area about its diameter 'd' is–

(a) $\frac{\pi D^4}{32}$ (b) $\frac{\pi D^4}{64}$

(c) $\frac{\pi D^4}{128}$ (d) None

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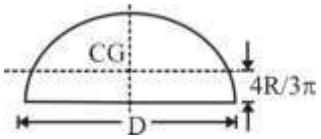
Ans. (c)



The moment of inertia of semicircular area about its diameter $= \frac{1}{2}\times\frac{\pi D^4}{64}$

$$\boxed{I = \frac{\pi D^4}{128}}$$

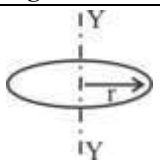
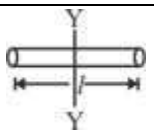
29. The moment of inertia of a solid cylinder of mass 'm', radius 'r' and length 'l' about the longitudinal axis or polar axis is–

(a) $mr^2/4$ (b) $mr^2/8$

(c) $mr^2/6$ (d) $mr^2/2$

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (d) The moment of inertia of a solid cylinder of mass 'm', radius 'r' and length '*l*' about the longitudinal axis or polar axis is $\frac{mr^2}{2}$.

Solid	About	Figure	M.O.I.
Ring	Through centre		$I_{YY} = mr^2$
Solid cylinder	Through centre		$I_{XX} = \frac{mr^2}{2}$
Solid sphere	Through centre		$I_{YY} = \frac{2}{5}mr^2$
Hollow sphere	Through centre		$I_{YX} = \frac{2}{3}mr^2$
Long uniform rod	Through centre		$\frac{1}{12}m\ell^2$

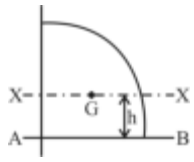
30. What is the Moment of Inertia of a Quarter circle about its Diametral Axis?

(a) $\pi d^4/128$ (b) $\pi d^4/256$

(c) $\pi d^4/64$ (d) $\pi d^4/36$

RRB-JE 29.08.2019, Ist Shift

Ans. (b) : $\bar{x} = \bar{y} = \frac{4r}{3\pi}$



Area of quarter circle (A) = $\frac{\pi r^2}{4}$

$I_{AB} = \frac{\pi r^2}{16} = \frac{\pi d^4}{256}$

31. The product of area and square of distance of centre of gravity of the area from that axis is known as-

(a) Second moment of area
(b) Mass moment of inertia
(c) Second moment of mass
(d) First moment of area

RRB-JE 29.08.2019, Ist Shift

Ans. (a) The product of area and square of distance of centre of gravity of the area from that axis is known as second moment of area (I).

$I = Ak^2$

Unit $\rightarrow m^4$

If $I = mk^2$, Then I is called second moment of mass

where, A = Area of section
K = Radius of gyration
m = mass of the body

32. Moment of inertia is a concept applicable in the case of

(a) a rotating body
(b) a body moving in a straight line
(c) a body at rest
(d) all of these

RRB JE 04-01-2015 (Red Paper)

Ans : (a) Moment of inertia is a concept applicable in the case of a rotating body.

- Moment of inertia is a tendency to resist rotational motion about a given axis. Sometimes it is also called second moment of mass (for 3D body).
- Generally there are two type of moment of inertia
  1. Mass moment of inertia, which is expressed as
     $I = mr^2$
     where, m = mass of rotating object
     r = distance from rotational axis
  2. Area moment of inertia, which is express as
     $I = Ak^2$
     where, A = Area of rotating object

33. A truss is said to be perfect when it satisfies the following conditions:

(a) $m = 2j + 3$ (b) $m = 3j - 2$
(c) $m = 2j - 3$ (d) $m = 3j + 2$

RRB-JE 30.08.2019, Ist Shift

Ans : (c) Types of truss–
1. Perfect truss
2. Imperfect truss
   (i) Deficient
   (ii) Redundant truss

1. Perfect truss–A truss which has just sufficient number of members to resist the loads without undergoing deformation in its shape.

2. Imperfect truss– In this truss the number of members are less or more than (2j – 3).

(i) Deficient truss–In this truss the number of members are less than that required for a perfect truss.

(ii) Redundant truss–In this truss the number of members are more than that of required for a perfect truss.

For a perfect truss - $m = 2j - 3$
For a deficient truss - $m < 2j - 3$
For a redundant truss - $m > 2j - 3$
where, $m \Rightarrow$ number of members
$j \Rightarrow$ number of joints

34. An example of rotational motion is-

(a) Spinning of earth
(b) Movement of a car on a straight road
(c) Motion of earth around the sun
(d) Movement of drawer of a table

RRB-JE 29.08.2019, Ist Shift

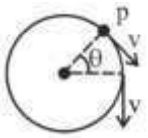
Ans. (a) : Motion of a body around a fixed line or its axis, is called rotational motion.
Examples : - Spinning of earth, motion of wheel or fan around its own axis etc.

35. A particle moves along a circular path with constant speed. What is the nature of its acceleration?

(a) its is zero
(b) It is Uniform
(c) Its direction changes
(d) its magnitude changes

RRB JE 21-12-2014 (09 Yellow Paper)

Ans : (c) When, a particle moves along a circular path with constant speed, then the magnitude of acceleration will be constant but its direction changes in every instant.



36. The weight of an object on the Moon is W_m and its weight on the Earth is W_e. Which of the following formulas is CORRECT?

(a) $W_m = 6 \times W_e$ (b) $W_m = 3 \times W_e$
(c) $W_m = (1/6) \times W_e$ (d) $W_m = (1/3) \times W_e$

RRB-JE 29.08.2019, Ist Shift

Ans. (c) : The mass of the moon is $\frac{1}{100}$ time and its radius $\frac{1}{4}$ time that of earth. As a result, the gravitational attraction on the moon is about one-sixth when compared to earth. If any object weight on the moon

surface = W_m and object weight on the earth surface = W_e then, $\boxed{W_m = \frac{W_e}{6}}$

37. In the case of perfect elastic collision, the coefficient of restitution is :

(a) 1.0 (b) 0.5
(c) Less than 1.0 (d) Zero

RRB JE 14-12-2014 (01 Red Paper)

Ans : (a) In the case of perfect elastic collision, the coefficient of restitution is one.

- For perfectly inelastic body, e = 0
- For perfectly elastic body, e = 1
- When the body is neither perfectly elastic & also nor perfectly inelastic then 0 < e < 1.
- Loss in kinetic energy during the collision of elastic body,

$$E_L = \frac{m_1.m_2}{2(m_1+m_2)}(u_1-u_2)^2\left(1-e^2\right)$$

Where, e = Coefficient of restitution

$$e = \frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}} = \frac{v_2-v_1}{u_1-u_2}$$

38. In a perfectly elastic collision:

(a) Linear momentum and K.E. both are conserved
(b) Only momentum is conserved
(c) Only K.E. is conserved
(d) None of them is conserved

RRB JE 14-12-2014 (06 Yellow Paper)

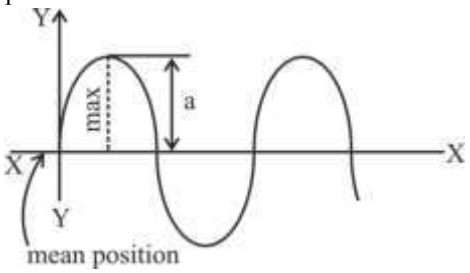
Ans : (a) In case of a perfectly elastic collision, both linear momentum and kinetic energy are conserved. In case of inelastic collision only linear momentum is conserved.
For perfectly elastic collision, e = 1
For perfectly inelastic collision, e =0
Where, e = coefficient of restitution

39. What is the magnitude of the maximum disturbance in the medium on either side of the mean value called?

(a) Frequency (b) Oscillation
(c) Amplitude (d) Wavelength

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (c) The magnitude of the maximum disturbance or displacement in the medium on either side of the mean value is called amplitude.
a = amplitude

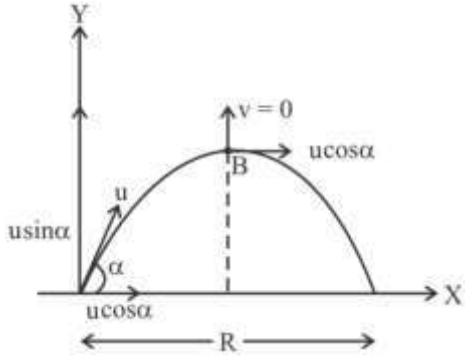


40. If 'α' is angle of projection and 'u' is velocity of projection for a projectile, then its horizontal range is given by:

(a) $R = (u^2 \sin 2\alpha)/g$ (b) $R = (u^2 \sin\alpha)/g$
(c) $R = (u^2 \cos 2\alpha)/g$ (d) $R = (u^2 \cos\alpha)/g$

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (a) The horizontal range



Range of a projectile

$$\boxed{R = \frac{u^2 \sin 2\alpha}{g}}$$

Range will be max, if $\alpha = 45^0$

- Time of flight (T) = $2t = \frac{2u\sin\alpha}{g}$
- Maximum height $(H) = \frac{u^2 \sin^2\alpha}{2g}$

Other Exams Questions

41. The shaded area under the acceleration Vs time curve of a particle gives

(a) the change in position
(b) the change in velocity
(c) the change in acceleration
(d) the change in acceleration rate

ISRO VSSC Technical Assistant 30.07.2023

Ans. (b) : The area under the acceleration versus time curve of a particle gives the change in velocity.
The area under the velocity versus time curve of a particle gives the displacement of the body.

42. Which of the following statements is true as per Newton's third law of motion?

(a) Every action has a reaction which is higher in magnitude and opposite in direction.
(b) Every action has a reaction which is lower in magnitude and opposite in direction.
(c) Every action has a reaction which is equal in magnitude and opposite in direction.
(d) Every action has a reaction which is equal in magnitude and similar in direction.

SJVNL Junior Field Engineer 22.06.2023, Shift-III

Ans. (c) : According to Newton's third law of motion every action has a reaction which is equal in magnitude and opposite in direction.

43. What is the relationship between each force, if there concurrent of forces acting on a body to Lami's theorem?

(a) Directly proportional to the sine of the angle between the other two forces

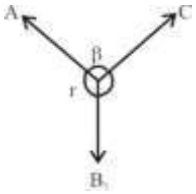
(b) Inversely proportional to the cosine of the angle between the other two forces

(c) Directly proportional to the cosine of the angle between the other two forces

(d) Inversely proportional to the sine of the angle between the other two forces

TPSC ITI Principal 2023

Ans. (a) : When three coplanar and concurrent forces act simultaneously at a point, achieving equilibrium among them, each force is directly proportional to the sine of the angle between the other two forces.



$$\frac{F_A}{\sin\alpha} = \frac{F_B}{\sin\beta} = \frac{F_C}{\sin\gamma}$$

44. In the context of the virtual work principle in continuum mechanics, which of the following statements is true about a system in equilibrium?

(a) Both conservative and non-conservative forces can do virtual work.

(b) Neither conservative nor non-conservative forces do virtual work.

(c) Only non-conservative forces do virtual work.

(d) Only conservative forces do virtual work.

BEL PE 17.12.2023

Ans. (a) : The virtual work principle in continuous mechanics the conservative and non-conservative forces are included.

45. For any system of coplanar forces, the condition of equilibrium is that the algebraic sum of.

(a) The vertical components of all the force should be zero

(b) The horizontal components of all the force should be zero

(c) Moments of all force about any point should be zero

(d) All these

IREL MT 24.09.2023

Ans. (d) : For any system of coplanar forces, the condition of equilibrium to be satisfied the following conditions.

- The vertical component of all the forces should be zero $\left(\Sigma F_y = 0\right)$
- The horizontal component of all the forces should be zero. $\left(\Sigma F_x = 0\right)$
- Moments of all forces about any point should be zero. $\left(\Sigma M = 0\right)$

$\Sigma F_x = 0, \Sigma F_y = 0, \Sigma M = 0$

46. An elevator is lifting a man of mass 50 kg. The acceleration of the elevator, which could cause a force of 800 N on the floor is _____ m/s^2. Take g = 10 m/s^2

(a) 16.0 (b) 6.0

(c) 1.6 (d) 0.6

TSPSC AEE 26.10.2023

Ans. (b) : Given,

Mass of man = 50 kg

Force = 800N

We know that,

Newton's second law,

$F_{net} = ma$

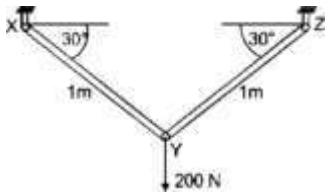
$F - mg = ma$

$800 - 50 \times 10 = 50 \times a$

$800 - 50 \times 10 = 50 \times a$

$a = 6 m/s^2$

47. Two steel trusses, XY and YZ of identical size support a load of 200 N as shown in fig. The length of the truss is 1 m. The force in the truss XY in Newton is–

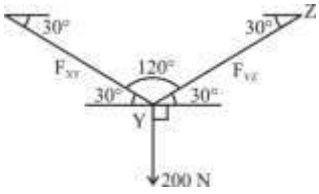


(a) 100 N (b) 200 N

(c) 150 N (d) 50 N

GPSC (GWSSB) AE 18.08.2023

Ans. (b) :



From lami's theorem-

$$\frac{W}{\sin\alpha} = \frac{F_{XY}}{\sin\beta} = \frac{F_{YZ}}{\sin\gamma}$$

$$\frac{W}{\sin 120^\circ} = \frac{F_{XY}}{\sin 120^\circ} = \frac{F_{YZ}}{\sin 120^\circ}$$

$$\frac{200}{\sin 120^\circ} = \frac{F_{XY}}{\sin 120^\circ} = \frac{F_{YZ}}{\sin 120^\circ}$$

$\therefore \boxed{F_{XY} = F_{YZ} = 200\ N}$

48. When trying to turn a key into a lock, _____ is applied.

(a) Lever
(b) Coplanar force
(c) Couple
(d) Moment

Kerala PSC Asst. Prof. 30.06.2023

Ans. (c) : When trying to turn a key into a lock couple is applied.

49. During elastic and inelastic collision, _____ is conserved.

(a) kinetic energy
(b) velocity
(c) viscosity
(d) momentum

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Ans. (d) :Elastic collision :-In an elastic collision both kinetic energy and momentum are conserved.

- **Inelastic collision-** In an inelastic collision momentum conserved but kinetic energy is conserved.
- Momentum, is conserved in both elastic and inelastic collision.

50. A particle of mass (m) moves in a x-y plane. The co- ordinates of the particle at any instant are given by $x=\alpha\cos\omega t$, $y=b\sin\omega t$, where α,b and ω are constants. What will be the angular momentum of the particle with respect to the origin of the coordinate system?

(a) $2\alpha b\omega m$ (b) $4\alpha b\omega m$
(c) $\alpha b\omega m$ (d) $3\alpha b\omega m$

BHEL ET Mech. 24.08.2023

Ans. (c) : Given that,

$x = \alpha\cos\omega t$

$y = b\sin\omega t$

$$V_x = \frac{dx}{dt} = -\alpha\omega\sin\omega t$$

$$V_y = \frac{dy}{dt} = b\omega\cos\omega t$$

The position vector of the particle with respect to the origin of coordinate system is.

$$\vec{r} = x\hat{i} + y\hat{j}$$

$$= \alpha\cos(\omega t)\hat{i} + b\sin(\omega t)\hat{j}$$

$$\mathbf{V} = V_x\hat{i} + V_y\hat{j}$$

$$= -\alpha\omega\sin(\omega t)\hat{i} + b\omega\cos(\omega t)\hat{j}$$

angular momentum of particle with respect to the origin of the coordinate system.

$$L = \vec{r}\times\vec{p}$$

$$= \vec{r}\times m\cdot\vec{v}$$

$$\left[\left(\alpha\cos(\omega t)\hat{i} + b\sin(\omega t)\hat{j}\right)\right]\times m\left[\left(-\alpha\omega\sin(\omega t)\right)\hat{i} + b\omega\cos(\omega t)\hat{j}\right]$$

$$= \alpha b\omega m$$

51. Tribology is related to:

(a) Friction, lubrication and wear
(b) Welded and riveted joints
(c) Steam production in boiler
(d) Cavitations

BHEL ET 24.08.2023

Ans. (a) : Tribology is related to Friction, lubrication and wear.

- **Friction-** Tribology involves the study of friction, which is the resistance to motion when two surface are in contact.
- **Lubrication-** Tribology also deals with lubrication, which is the application of a substance (lubricant) between surfaces to reduce friction and wear.

52. What type of friction in cup design is recommended for set screw?

(a) Sliding
(b) Rolling
(c) Static
(d) None of the above

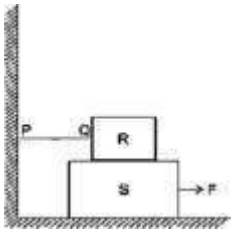
WBPSC (AE) 05.11.2023

Ans. (b) : Sliding friction, the total force require to raise the load is quite large as compared to that required in rolling friction.

Hence length of handle in some cases become extremely large and thus it is impractical to use cups with sliding friction.

Rolling friction refers to the resistance encountered by a rolling object when it moves over a surface.

53. A block R of mass 100 kg is placed on a block S of mass 150 kg as shown in the figure. Block R is tied to the wall by a mass less and inextensible string PQ. If the coefficient of static friction for all surfaces is 0.4, the minimum force F (in kN) needed to move the block S is-



(a) 0.69 (b) 0.88
(c) 0.98 (d) 1.37

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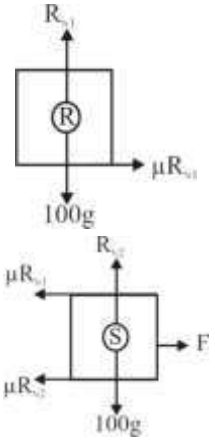
Ans. (d) : Making free body diagram of each block-



Balancing forces in positive x direction

$F = \mu R_{N1} + \mu R_{N2} = \mu(R_{N1} + R_{N2})$

RN_1 = Normal reaction force on block R and RN_2 = Normal reaction force on block S

Given-

$\mu = 0.4$

$R_{N1} = 100g = 100 \times 9.81 = 981$ N

$R_{N2} = (100 + 150)g = 250 \times 9.81 = 2452.3$

Minimum force (F) is

$F = \mu(R_{N1} + R_{N2})$

$F = 0.4 \times (981 + 2452.5) = 1373.4$ N

$= 1.37$ kN

54. Moment of Inertia of a thin spherical shell is

(a) Mr^2 (b) $\frac{2}{3}mr^2$

(c) $\frac{2}{5}mr^2$ (d) $\frac{mr^2}{2}$

WBPSC Asst. Prof. 2023

Ans. (b) : Moment of Inertia of a thin spherical shell

$= \frac{2}{3}mr^2$

Moment of Inertia of a solid sphere

$= \frac{2}{5}mr^2$

55. Moment of inertia about an axis perpendicular to the plane of an area is known as

(a) Polar moment of inertia
(b) Moment of inertia
(c) First moment of area
(d) None of the above

GPSC AE 02.04.2023

Ans. (a) : Moment of Inertia about an axis perpendicular to the plane of an area is known as polar moment of Inertia. It is denoted as J.

For circular member

$J = I_{xx} + I_{yy}$

$\boxed{J = \frac{\pi}{32}d^4}$

56. The radius of gyration of a circular lamina of diameter 'd' is given by which one of the following values?

(a) $\frac{d}{2}$ (b) d

(c) $\frac{d}{4}$ (d) $\frac{d}{16}$

UKPSC AE (Re-Exam) 14.08.2023, Paper-I

Ans. (c) : We known that,

$I = AK^2$

Radius of gyration (K) = $\sqrt{\frac{I}{A}}$

Where, I = Moment of inertia of circular lamina = $\frac{\pi d^4}{64}$

A = Area of circular cross-section = $\frac{\pi d^2}{4}$

Now, Radius of direction (K) = $\sqrt{\frac{\frac{\pi d^4}{64}}{\frac{\pi d^2}{4}}}$

$= \sqrt{\frac{\pi d^2}{64} \times \frac{4}{\pi d^2}}$

$= \sqrt{\frac{d^2}{16}}$

$= \frac{d}{4}$

57. The equation of motion of a body over a smooth surface is given by the relation s = 10 t + 2t² where (s) is in metres and (t) in seconds. If the mass of the body is 20 kg, find the magnitude of force responsible for the motion :

(a) 50 N (b) 60 N
(c) 70 N (d) 80 N

Kerala PSC AE 23.11.2023

Ans. (d) : Give,

The equation of motion $S = 10t + 2t^2$ ...(i),

$s = ut + \frac{1}{2}at^2$ ...(ii)

Comparing from (i) and (ii) –

$\frac{1}{2}a = 2$

$a = 4$

Using Newton's second law,

$F = m.a = 20 \times 4 = 80$ N

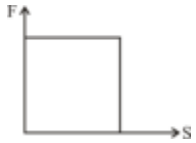
58. The area under the Force vs Displacement curve of an object gives the

(a) acceleration of the object
(b) velocity of the object
(c) work done by the object
(d) none of the above

ISRO VSSC Technical Assistant 30.07.2023

Ans. (c) : The area under the force vs displacement curve of an object gives work done by the object

$$\boxed{W = F.S}$$



59. Two bodies of masses 10 kg and 20 kg respectively, are dropped simultaneously building. Which of the following options is correct when the bodies are 2 m above the earth surface

(a) Same acceleration
(b) Same momentum
(c) Same kinetic energy
(d) Same potential energy

UKPSC AE (Re-Exam) 14.08.2023, Paper-I

Ans. (a) : When two bodies of different masses are dropped from the same height, they will experience the same acceleration due to gravity, which is approximately 9.8 m/s^2 near the Earth's surface.

60. Which of the following statements is INCORRECT?

(a) A glider put into space with some initial velocity is not a projectile
(b) For a ball thrown at 45º with the horizontal and with kinetic energy E, the kinetic energy at the highest point during the flight will be 2/3 E.
(c) The sum of maximum heights attained by a projectile does not depend on the angle of projections which give the same horizontal range.
(d) When a shell fired from a gun at an angle to the horizontal explodes in mid air, the center of mass of its fragments moves along the parabolic path of the original shell

APPSC AEE 22.08.2023, Shift-II

Ans. (b) : The kinetic energy of a projectile is dependent on its velocity, which varies throughout its trajectory, the velocity is momentarily zero, so the kinetic energy is also zero.

The kinetic energy at the highest point would be 0, not 2/3 E.

61. The angle of projection at which the horizontal range is four times the maximum height of a projectile

(a) 36° (b) 45°
(c) 56° (d) 76°

ISRO SAC 21.06.2023

Ans. (b) : Range of projectile is given by

$$R = \frac{u^2 \sin 2\theta}{g}$$

Height of projectile is given by

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

Given, $R = 4H$

$$\frac{u^2 \sin 2\theta}{g} = \frac{4 \times u^2 \times \sin^2 \theta}{2g}$$

$2 \sin\theta\cos\theta = 2 \times \sin^2\theta$

$\tan\theta = 1$

$$\boxed{\theta = 45^o}$$

62. If a stone is released from the top of 50m high tower, then its velocity just before touching the ground will be _____ m/s.
Take g = gravitational acceleration

(a) 10 (b) $10\sqrt{g}$
(c) 100 (d) $\sqrt{g}$

TSPSC AEE 26.10.2023

Ans. (b) : The final velocity V just before hitting the ground can be calculated using the formula.

$V^2 = u^2 + 2gh$ .....(i)

$u = 0$

g = gravitational acceleration

$h = 50$

Putting the values of equation (i) in,

$V^2 = 0^2 + 2gh$

$V^2 = 2gh$

$V = \sqrt{2gh}$

$V = \sqrt{2 \times g \times 50}$

$V = \sqrt{100 \times g}$

$$\boxed{V = 10\sqrt{g}}$$

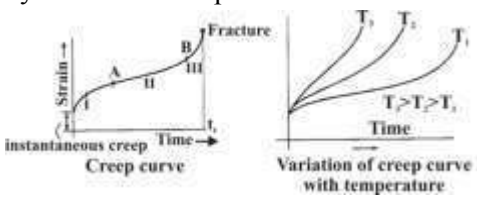
02. Material Science

Important Mechanical Properties of Metals

Hardness	Hardness is the resistance offered by surface of the material to indentation.
Stiffness	The ability of material to resist elastic deformation or deflection is called stiffness.
Elasticity	The property of a material by virtue of which material regains its original form after removal of load is elasticity.
Plasticity	It is just opposite to elasticity which means ability of the material to undergo permanent deformation even after removal of the load.
Ductility	Property of a material enabling it to be drawn into wire with the application of a tensile force.
Resilience	It is the strain energy that can be absorbed by the material without plastic deformation upto elastic limit.
Toughness	Toughness is the maximum strain energy that can be absorbed by the material upto fracture.
Strength	The resistance offered by a material on application of external force is called strength.
Malleability	It is the ability of a metal to be formed into a variety of shapes by hammering it or rolling it into thin sheets.
Fatigue	The behaviour of the material under fluctuating load.
Creep	The permanent deformation of a material over a period of time at constant load and at elevated temperature is called creep.
Anisotropy	When the properties of a material are dependent on the direction.
Isotropy	When the properties of a material are same in all the direction.

Creep-

- It is slow and progressive deformation of material over a period of time at constant load and at a temperature equal to or greater than recrystallization temperature.



- As soon as the material is loaded, some instantaneous creep will appear in the material.
- **In the primary creep** region, strain rate are decreasing because work hardening.
- **In the secondarycreep** region the creep rate is constant, and a balance between recovery and strain hardening is obtained here and material also becomes soften.
- **In Tertiary creep** region there will be a limit upto which work hardening can happen in the material and slowly recrystallization phenomena take over and this increases the strain rate and there will be facture in the material.

Fatigue Strength-

- When a material is subjected to cyclic or repeated loading, failure occurs before the yield strength is known as fatigue strength.
- S-N curve is drawn for fatigue testing.
- In fatigue failure, the S-N curve of a material represents the relation between stress amplitude and number of cycles to failure.

Steel-

- In steel, C atoms occupies interstitial sites of Fe.

Plain Carbon Steel-

Low carbon steel	Medium carbon steels	High carbon steels
• Carbon present is not enough to strengthen them by heat treatment, hence are strengthened by cold work. **Application-** Tin cans automotive body components structural shape	• Heat treatable (austenitizing, quenching & tempering) **Application-** • Gears • Railway tracks • Machine parts	• Heat treatable & used in tempered or hardened conditions. **Application-** •Razors • Hacksaw blades

Alloy Steel-

- High strength structural steel
- Tool steels
- Stainless steel

Stainless Steel-

- Stainless steel consists minimum 12% Cr along with other alloying elements, thus highly corrosion resistant owing to presence of **Chromium Oxide.**

Martensitic stainless steel	Ferritic stainless steel	Austenitic stainless steel
• Chromium = 12 to 14% Carbon = 0.12 to 0.35% Rest iron • Easily welded and machined. • Magnetic	• Chromium = 16 to 18% Carbon = 0.12% Rest iron • Better corrosion resistance property	• Chromium = 18% Nickel = 8% Rest iron • Non-magnetic Ni stabilizer the austenitic phase assisted by C and N. • Also called 18/8 steel

Effect of Alloying Element in Steel-

Element	Effect on Steel Properties
Sulphur (S)	When combined with manganese, it improves mach-inability.
Carbon	Hardness, Tensile strength, Machinability
Silicon	• Promotes graphitization • Acts as a deoxidizer • Strengthens low alloy steels
Copper	• Acts as strengthening agent • Increases resistance to atmospheric corrosion
Aluminium	• Acts as a deoxidizer
Molybdenum (Mo)	It improves hardenability, strength, abrasion resistance, elevated temperature strength, creep resistance.
Cobalt (Co)	It improve red hardness at elevated temperature.
Chromium (Cr)	It improves corrosion and oxidation resistance. It also increases hardability and wear resistance.
Nickel (Ni)	It improves toughness, impact resistance and hardnability.
Tungsten (W)	It improves abrasive resistance and hot strength & hardness.
Vanadium (V)	It improves strength, toughness hardness at elevated temperature.

Note-

- Stainless steel are highly corrosion resistance so used in medical instruments and house hold appliances and in utensils.
- High speed steels are used for making cutting tools to be used at high speed.
- These are M series (Molyblendum type- 10% Mo)
  T series (Tungsten type- 12-18% W)
- 18-4-1 is the extensively used high speed steel.
  (18% W + 4%(Cr) + 1% V)

Classification on the basis of oxidation of steel-

(i) killed Steel-

- If the quantity of Si is such that trapped O_2 is completely remove, it is called killed steel.

(ii) Semi Killed Steels-

- If the quantity of Si is such that the removal of O_2 is only partial, it is called semi-killed steel.

Designation of Steels-

Steels are designated by following three properties-

- Tensile strength
- Carbon content
- Composition of alloying element

Example-Fe 360 Steel with minimum tensile strength of 360 N/mm^2

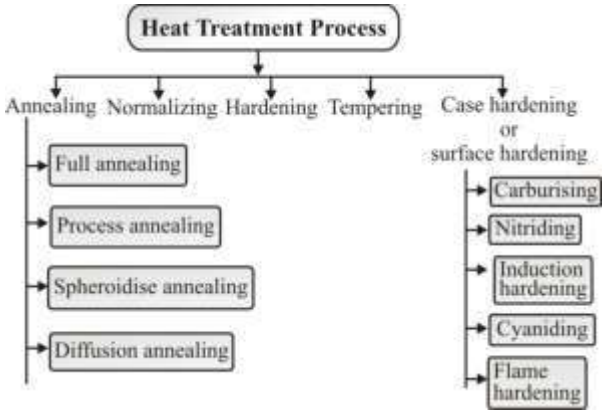
For Plain Carbon Steel-

- A figure containing 100 times the average percentage of carbon.
- A letter C
- A figure indicating 10 times the percentage of Mn.

Example-55C 4, 0.55%C 0.4% Mn

Heat Treatment-

- Heat treatment is an important operation in the manufacturing process of many machine parts and tools which imports high mechanical properties to steel.



- The purpose of heat treatment is to achieve any one or more objectives as follows-

(i) To remove strain hardening of a cold worked metal and to improve its ductility.
(ii) To relieve internal stresses set up during cold-working, casting, welding and hot-working treatments.
(iii) To remove gases from castings, to soften a metal to improve its machinability, and to increase the resistance to wear, heat and corrosion.
(iv) To improve the cutting ability, i.e., hardness of a steel tool, to improve grain structure after hot working a metal and to remove effects of previously performed heat-treatment operations.
(v) To refine grain structure after hot working a metal.
(vi) To soften and toughen a high carbon steel piece.
(vii) To harden non-ferrous metals and alloys, especially aluminium alloys and to produce a single phase alloy in stainless steel.

Annealing-

Quenching Medium →Furnace

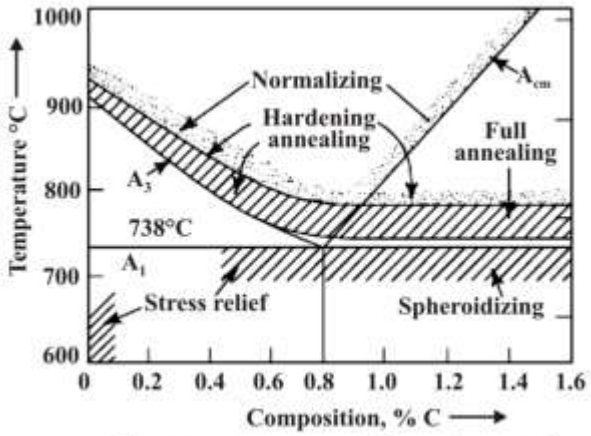
- The main purpose of annealing is to reduce the hardness of a material.
- A material is exposed to an elevated temperature for an extended time period and then slowly cooled.

Normally, annealing is carried out to-

(i) Increase softness, ductility and toughness
(ii) Produce a specific microstructure.
(iii) To relive the internal stress of a material.
(iv) To restore ductility to perform the further operation on the material.
(v) To increase the machinability of the material.

An annealing process consists of three stages:

(i) Heating to the desired temperature.
(ii) Holding or 'soaking' at that temperature
(iii) Cooling, usually to room temperature.



Heat treatment range for carbon steels

Full Annealing-

- This operation removes all structural imperfections by complete recrystallization. This operation is often utilized in low and medium carbon steels that will be machined.

This operation consist of-

(i) Heating the hypoeutectoid steel to about 50-70°C above the upper critical temperature (for hypoeutectoidsteels) and by the same temperature above the lower critical temperature for hypereutectoid steelsuntil equilibrium is achieved.
(ii) The alloy is then furnace cooled i.e., the heat-treating furnace is turned off and both furnace and steelcool to room temperature at the same rate, which takes several hours.The microstructural product of full anneal is coarse pearlite thatis relatively soft and ductile.

Process Annealing-

- This is a heat treatment that is used to reduces the effects of cold work, i.e. to soften and increase the ductility of a previously strain hardened metal.
- Process annealing is very useful in **mild steels and low carbon steels.**

The process is as follows-

(i) The steel is heated to 550-650°C, which is just below the lowercritical temperature on iron-carbon diagram for steel.
(ii) Stresses throughout the metal are relieved and recrystallizationcauses new grains to form and grow.

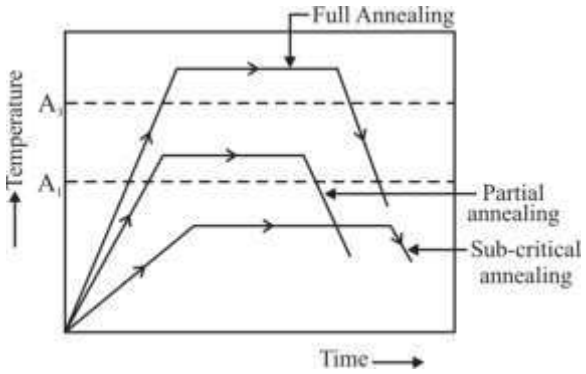
Spheroidize Annealing-

- This process is applied to high carbon steels which are difficult to machine.
- It causes the formation of all carbides in the steel in the form of very small globules or spheroids like spheres.
- The process consists of heating the steel near the lower critical temperature (730 - 770°C), holding at this temperature and then cooling slowly to 600°C.

Diffusion Annealing-

- Diffusion annealing or homogenizing is applied to alloy steel ingots and heavy complex castings for eliminating the chemical in homogeneity within the separate crystals by diffusion.
- Diffusion annealing is carried out at temperature 1000 - 1200°C.

Various Type of Annealing-



Where,

A_1 = Lower critical temperature

A_3 = Upper critical temperature

Summary Table-

Type of Annealing	Description	Temperature range
1. Full Annealing	• Ductility and toughness increases refine grain structure. • It is generally done after cold working process • Adopted for steel casting and ingots.	• Full annealing consist of heating steel **30 - 50°** above the critical temperature for **hypo-eutectoid steel** and 50°C above the lower critical temperature **for hyper-euctoid steel.**
2. Process Annealing	It is usually carried out to remove the effects of cold working and to soften it to make it suitable for further plastic deformation as in case of sheet and mill industries.	Cold work steel is heated below or close to the lower critical temperature above 550°C-650°C
3. Spheroidize annealing	• This process is applied to high carbon steel which are difficult to machine. • Knot form of cementite is converted into granular form.	• Close below or close above the lower critical temperature. • Cyclic heating & cooling around lower critical temperature & then finally cooled slowly.

4. Diffusion Annealing	• Eliminate the chemical inhomogenousity. • It is applied to steel ingots and heavy complex casting.	• It is carried out at 1000 - 1200°C • Hold for some time. • Then cooling in furnace about 800 - 850°C. • Further cooled by air to the room temperature.

Normalizing-

- **Quenching Medium -** Air
- This is used as a finishing treatment for carbon steels giving higher strength than annealing. There is no serious loss of ductility too.
- Involves heating the steel component 30° - 50° above the upper critical temperature for **hypo eutectoid and hyper eutectoid steel** holding at that temperature for a short period and subsequently cooling in air at room temperature. This is known as air quenching.
- Normalizing raises the yield point ultimate tensile strength and impact strength in steels. Normalized steels are harder and stronger but less ductile than annealed steels with the same composition.

Result-

- Normalizing refine grain structure, improve machinability increase strength and toughness and remove internal stresses.

Difference Between Annealing and Normalizing-

Annealed Material	Normalized Material
Uniform grain size distribution.	Comparatively less uniform grain size destruction.
Cycle time is more	Cycle time is less due to fast air cooling.
Least residual internal stresses	Slightly more internal stresses
Pearlite structure is coarse.	Pearlite structure is fine.
Less hardness, tensile strength and toughness.	Comparatively more hardness tensile strength and toughness.
It is done to increase its ductility by reducing hardness & brittleness	It is done to harden the steel slightly.
More expensive	Less expensive than annealing.

Hardening-

- Hardening is a process in which steel heated to austenite temperature held at this temperature and then quenched in water oil or molten salt bath.
- **Temperature range-**

• 30°- 50°C above the upper critical temperature for hypo eutectoid steel.

• 30°-50°C above the lower critical temperature for hyper eutectoid steels.

- After hardening, steel must be tempered to reduce brittleness, relieve the internal, stress caused by hardening and to obtain the desire mechanical properties of steels.
- Hardening followed by tempering is to increase the mechanical properties of steels.
- Order of cooling rates of quenching medium.

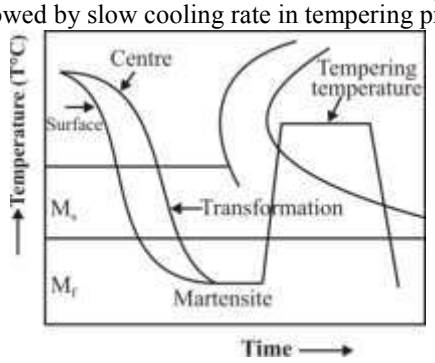
Salted both > Water > Mineral oil

Key Points-

- Oil bath →More uniform cooling than water quenching is followed by tempering to reduce internal stresses developed.

Tempering-

- Brittleness and & internal stresses developed during hardening is reduced by tempering process.
- The steel is reheated below lower temperature followed by slow cooling rate in tempering process.



Note-

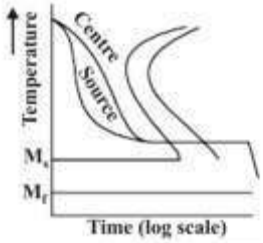
- This process reduces brittleness, increases ductility relieves internal stresses and improves toughness.

High temperature tempering (500 - 650°C)	Sorbite
Medium temperature (350 - 500°C)	Troostite **Application** (in spring & dies)
Low Temperature (on 250°C)	Martensite heated at 250°C cooled slowly to relevance internal speed.

Special Tempering Process-

Austempering- (Isothermal quenching)

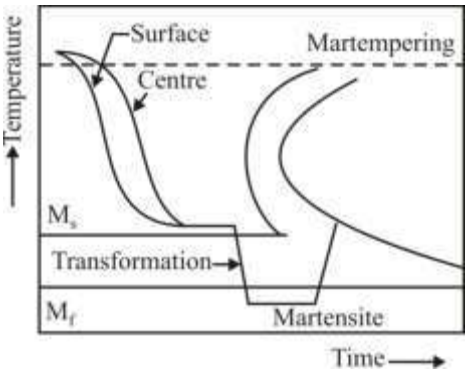
In this process, steel is heated above critical temperature (at about 875°C) then it is quickly quenched a little above $M_s$temperature so as miss the nose of TTT curve. And maintain there at the same temperature for prolonged period so that complete austenite is transformed into Bainite.



Austempering on the TTT curve

Mar-tempering-

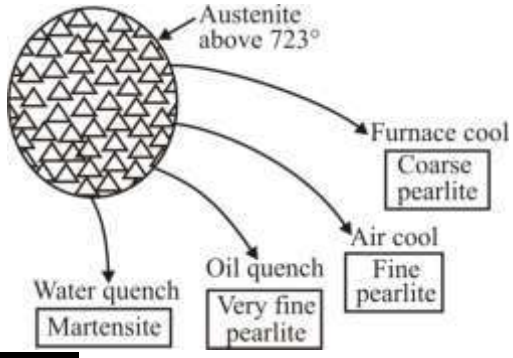
- In this process, hardened steel is heated above the critical temperature and then quenched in two medium.
- It is also known as stepped quenching or interrupted quenching.
- First hold for some time and then quenched in water to a temperature of 300°C.
- After holding there for a certain time, the steel is allowed to cool gradually in air.
- During this process austenite transform into marten site.



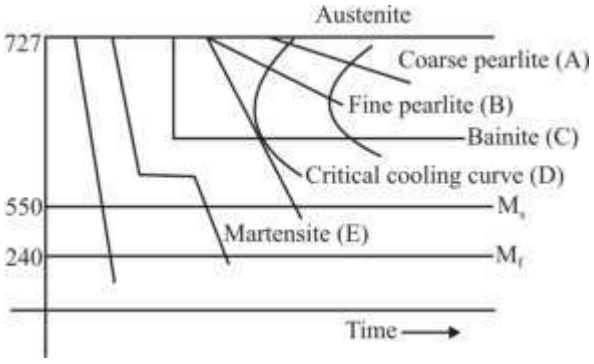
Key Point-

Martempering minimize cracks, distortions and internal stresses while increases toughness.

Quenching of Steel with Different Medium-



TTT Curve-



- Time-temperature transformation (TTT) curve is used which relates the transformation of austenite in different time and temperature conditions.
- This curve is also known as C-Curve, S-Curve, Bains curve or Isothermal transformation curve.

Case Hardening-

Carburizing-

- In carburizing the carbon content of the surface layer is increased is to obtain a hard layer on the work piece surface after heat treatment.
- The surface layer is enriched with carbon upto 1%. Carburizing is followed by hardening and low temperature tempering.

Type of Carburizing	Description
Pack carburizing	• Component packed in box with carburizing agent **(e.g. char coal)** and an energizer **(e.g. barium carbonate)** •Heated to **850 - 890°C** for diffusion of carbon in a furnace for **12 to 72 hours** •Case depth = 0.1 - 1.5 mm
Liquid carburizing	•Heated in container filled with a molten salt. **(e.g→Sodium carbonate)** •Heated to **950°C** • If only selected portion of the components are to be carburized then remaining portions are covered by Cu plating.
Gas carburizing	• Component are heated and surrounded by hydrocarbon gas (such as methane, carbon mono oxide) in the furnace. • Partial carburizing not possible.

Key Point-

- Carburizing is followed by hardening and low temperature tempering.
- No heat treatment required after nitriding.
- Hardness in surface hardening followed by sequence-

  Nitriding > Cyniding > Carburizing

- Hardening of steel must followed by tempering to reduce brittleness and relieve internal stresses.

Nitriding-

- In nitriding, the N content of the surface is increased, this is done by heating the atmosphere of NH_3 gas and the parts to be nitrided are placed in an air tight container.
- NH_3 is passing continuous through the work pieces at a temperature of 500 to 650°C, NH_3.

Key Point-

- Nitriding is carried out in the ferritic region.
- No phase change occurs after nitriding.
- During nitriding, pure NH_3 decomposes to yield nitrogen which enters the steel.

Cyaniding-

- In cyaniding a case of high hardness and wear resistance is produced on C-alloy steels. Work is immersed in molten salt bath containing NaCN which is heated to 820 - 860°C this is usually followed by water quenching.

Induction Hardening-

- The heat treatment is given to the surface only by supplying excessive heat to the surface followed by quenching.
- The structure of core remains unchanged because it is not affected by heat.

Flame Hardening-

- The process consists of heating the surface of medium carbon steel by high temperature gas flame at 2400°C - 3300°C and immediately cooling in air or water.
- Heat may be supplied by oxyacetylene torch.
- As soon as the desire temperature is achieved water immediately sprayed which cools the surface.

Various Surface Hardening Process-

Process	Element added to surface	Metal hardened	Procedure	Application	Character
Induction hardening	None	Medium carbon steel, cast iron	Heated between C_u induction coil with high frequency current then quenched.	Used for hardening surface of small component like shaft and sharp tool, crank shafts, gears, cams.	**Depth -** 0.7 - 6 mm
Flame hardening	None	Cast iron medium carbons steel	Localized heating with gas flames acetyl one, propane or natural gas.	M/C tool guide way, lathe beds, axles, piston rod.	**Depth-** 0.7 - 6 mm
Carburizing	C	Low carbon steel	Carburizing is done **920° - 950°** in the atmosphere of carbon.	Gears, cars shafts, bearing piston pin clutch plates.	**Case depth** 0.5 - 1.5 mm
Nitriding	N	Stainless steel alloy steel HSS	Heating the steel in atmosphere of NH_3 gas. • Temperature Range→ 500 - 590°C	Gears, shafts boring bars, cutters.	**Depth-** 0.1 - 0.6 mm
Cyaniding	C & N	Low carbon steel	Heat steel at 760° - 850°C in a molten both of NaCn solution followed by water or oil quenching.	Bolts, nuts, screws, small gears.	**Depth-** 0.025 - 0.25 mm

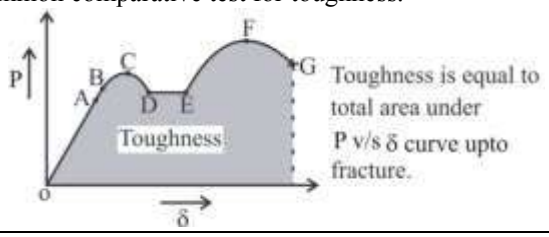
RRB Previous Years Questions

1. The property of a material which enables it to resist fracture due to high impact loads is known as :

(a) elasticity (b) endurance
(c) strength (d) toughness

RRB J.E 29-08-2019 (Ist shift)

Ans. (d) :Toughness :- The property of a material which enables it to resist fracture due to high impact load or it is the property of material which enables it to absorb energy without fracture. Bend test used for common comparative test for toughness.



2. The property of a material by which it can be beaten or rolled into sheets is known as :

(a) Malleability (b) Ductility
(c) Plasticity (d) Elasticity

RRB-JE 29.08.2019, Ist Shift
RRB JE 14-12-2014 (01 Red Paper)

Ans. (a) :

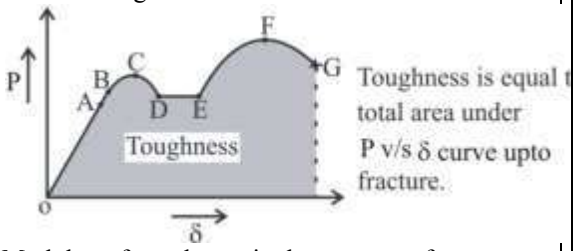
- Malleability is the property of material by which it can be beaten or rolled into thin sheet.
- Malleability of material is temperature dependent with rise in temperature the malleability of material increases.
- The most malleable metal is gold.

3. The impact strength of a material is an index of its-

(a) Toughness
(b) Tensile Strength
(c) Capability of being cold worked
(d) Hardness

RRB JE 14-12-2014 (06 Yellow Paper)

Ans.(a) :Toughness–Toughness is the ability of a material to absorb energy and plastically deform without fracturing.



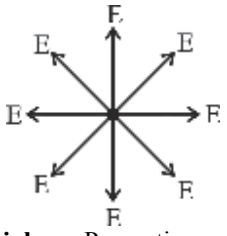
Modulus of toughness is the amount of energy per unit volume that a material can absorb before rupturing.

4. The materials having same elastic properties in all directions are called :

(a) ideal materials (b) uniform materials
(c) isotropic materials (d) real materials

RRB-JE 30.08.2019, Ist Shift

Ans. (c) : The materials having same elastic properties in all directions at a given point is called isotropic material.



Anisotropic materials – Properties such as young's modulus change with direction at a given point in the object is called anisotropic. Common examples of anisotropic materials are wood and composites.

5. The malleability is the property of a material by virtue of which the metal……..

(a) Can be rolled or hammered into sheet
(b) Regains its shape and size after the removal of external forces
(c) Retains the deformation produced under load permanently
(d) Can be drawn with the application of tensile force

RRB JE CBT-II 31.08.2019 IInd Shift

Ans. (a) : The malleability is the property of a material by virtue of which the metal can be rolled or hammered into sheet.

Malleability is the ability of a metal to exhibit large deformation or plastic response when being subjected to compressive force.

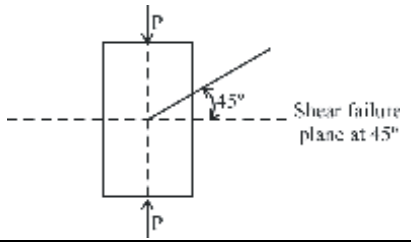
6. In compression test, the crack of the specimen of the cast iron will be at–

(a) The axis of load
(b) An oblique plane
(c) At right angles to the axis of specimen
(d) Will not be

RRB JE [Exam Date : 21-12-2014 (Bhopal)]

Ans : (b) Cast iron is a–

- Brittle material,
- Strong in compression.
- Moderate in shear.
- Weak in tension.
- In this material crack will occur at an oblique (45°) plane.



7. Which of the following materials has the maximum ductility?

(a) Aluminium (b) Nickel
(c) Tungsten (d) Iron

RRB-JE 29.08.2019, Ist Shift

Ans. (a) : As per given option, aluminium has the maximum ductility.

- Ductility is the property of a material enabling it to be drawn into wire with the application of a tensile force.
- In order of decreasing ductility - Gold & Platinum > Mild steel > Copper >Aluminium> Nickel > Zinc > Tin > Lead

8. Which of the following materials has nearly zero coefficient of expansion?

(a) Silver (b) Selenium
(c) Invar (d) Stainless Steel

RRB-JE 29.08.2019, Ist Shift

Ans. (c) : A nickel steel alloy containing about 36% nickel is known as Invar.

- Invar has nearly zero coefficient of expansion. So it is widely used for making pendulums of clocks, precision measuring instruments etc.

9. The ability of a material to resist deformation or deflection under stress is known as–

(a) Ductility (b) Mechanical strength
(c) Stiffness (d) Toughness

RRB JE CBT-II 31.08.2019 IInd Shift

Ans :(c) The ability of a material to resist deformation or deflection under stress is known as stiffness.

$$\text{Stiffness (K)} = \frac{\text{Load (W)}}{\text{Deformation } (\delta)}$$

If $\delta = 1$

Then $\boxed{K = W}$

10. The stiffness is the ability of a material to resist-

(a) Deformation under stress
(b) Externally applied forces with breakdown or yielding
(c) Fracture due to high impact loads
(d) To relieve internal stress

RRB-JE 30.08.2019, Ist Shift

Ans. (a) : The stiffness is the ability of a material to resist deformation under stress.

$$K = \frac{W}{\delta}$$

K = stiffness
W = load
□ = displacement produced by the load

11. The ability of a material to deform without breaking is called :
(a) resilience (b) creep
(c) plasticity (d) elasticity

RRB JE 14-12-2014 (02 Red Paper)

Ans. (c) : The ability of material to deform without breaking is called plasticity.

Resilience–Resilience is defined as energy stored by a member within elastic limit.

Creep–If a constant load applied for long time of period, then slow and permanent deformation is occurred, that is called creep.

Plasticity–A permanent deformation of material beyond elastic limit called plasticity.

Elasticity–It is the ability of material to regain its original state after the removal of applied load.

12. Hypoeutectoid steel consists of-
(a) Primary ferrite and pearlite
(b) Primary cementite and pearlite
(c) Proeutectoid cementite, pearlite and transformed ledeburite
(d) Pearlite

RRB-JE 30.08.2019, Ist Shift

Ans. (a) : Hypoeutectoid steel Consists of Primary Ferrite and Pearlite

- The steels which contain less than 0.8% carbon are known as hypoeutectoid steel.
- The steels which contain 0.8% carbon are known as eutectoid steels which consists entirely pearlite.
- The steels which contain above 0.8% carbon are known as hyper – eutectoid steels which consists of cementite and pearlite.
- Cementite consists of 93.33% iron and 6.67% carbon
- Pearlite consists of 87% ferrite and 13% cementite.

13. A steel with 0.8% carbon and 100% pearlite is called-
(a) Eutectoid steel
(b) Hypo-eutectoid steel
(c) Hyper eutectoid steel
(d) Pro eutectoid steel

RRB-JE 29.08.2019, Ist Shift

Ans : (a) A steel with 0.8% carbon and 100% pearlite is called eutectoid steel.

Type of steel	% of carbon
1. Hyper Eutectoid	0.8% (or 0.83%) to 1.7%
2. Hypo-Eutectoid	0.008% – 0.8%
3. Eutectoid	0.8%

14. Which of the following is/are a ferromagnetic material?
(a) Tungsten (b) Nickel
(c) Copper (d) Aluminium

RRB-JE 29.08.2019, Ist Shift

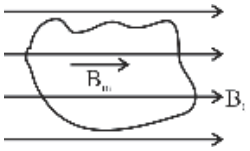
Ans. (b) : If ferromagnetic materials is held near to magnet, then it strongly attracted by a magnet.

- Ferromagnetic materials do not lose their magnetism on removal of external magnetic field i.e. they are permanent magnets.
- These materials are → Iron, Nickel and cobalt.

15. Which of the following is an example of paramagnetic material?
(a) Gold (b) Tantalum
(c) Copper (d) Silver

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (b) Paramagnetic substances are those in which each individual atom/molecule/iron has a net non-zero magnetic moment of its own.



When such substances are placed in an external magnetic field they get weakly magnetised in the direction of the magnetising field.

Example – Tantalum, Aluminium, chromium, Mangnese, Platinum, Tungusten etc.

16. The temperature at which the new grains are formed in the metal is called?
(a) Lower critical temperature
(b) Upper critical temperature
(c) Eutectic temperature
(d) Recrystallisation temperature

RRB JE 28-08-2015 (Shift-I)

Ans : (d) Recrystallisation is defined as the process in which grains of a crystal structure come in a new structure or new crystal shape.

The driving for recrystallation is the stored strain energy in the material.

17. A condition of timber during seasoning in which the different layers of wood are under stress by being under compression across the grain (usually due to rapid surface drying in the kiln).
(a) Case hardening (b) Air seasoning
(c) Air drying (d) Strain softening

RRB SSE 03-09-2015 (Shift-I)

Ans : (a) Case hardening–The exposed surface of timber dries rapidly.

It therefore shrinks and is under compression. The interior surface which has not dried completely in under tension. This defect is known as the case-hardening.

18. In Rockwell hardness testing method, the hardness of a material is measured by–
(a) Material failure
(b) Depth of indentation

(c) Elongation of material
(d) Surface roughness

RRB JE CBT-II 31.08.2019 IInd Shift

Ans :(b) The Rockwell's hardness test is generally, performed, when quick and direct reading is desirable.

- This test is also performed when the materials have hardness, beyond the range of Brinell's hardness Test.
- In this testing method, the hardness of a material is measured by depth of indentation.
- This test has nine scales of hardness (A to H and K). But B and C scales are widely used.

19. A carbon steel having a Brinell hardness number 100 should have ultimate tensile strength closer to-

(a) 220 N/mm^2 (b) 150 N/mm^2
(c) 800 N/mm^2 (d) 350 N/mm^2

RRB-JE 30.08.2019, Ist Shift

Ans. (d) : Brinell hardness number (BHN) = 100
Ultimate tensile strength = ?
Ultimate tensile strength = 3.5 × BHN

= 3.5 × 100

= 350 N/mm^2

20. Cup and cone type fracture occurs in the case of-

(a) Cast iron
(b) Round specimen of ductile metals
(c) Tough steel
(d) Soft brass

RRB JE 28-08-2015 (Shift-III)

Ans :(b) Cup and cone type fracture occurs in case of round specimen of ductile materials.

21. The word 'Brinell' is associated with

(a) soil testing
(b) tensile testing
(c) hardness testing
(d) testing of seasoning of wood

RRB JE 14-12-2014 (03 Green Paper)

Ans. (c) : The word 'Brinell' is associated with hardness testing.

- The Brinell hardness number (B.H.N) is obtained by dividing the applied force by the spherical surface area of the indentation.

$$B.H.N = \frac{\text{applied load in kg}}{\text{area of impression or indention in mm}^2}$$

$$B.H.N. = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)} \quad (kgf/mm^2)$$

where, P = Applied load (kgf)
D = diameter of ball used in mm.
d = diameter of impression produced in mm.

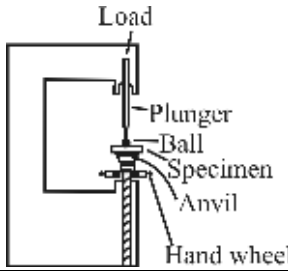
22. What is the common between Rockwell, Brinell and shore? They pertain to–

(a) Surface finish (b) Heat treatment
(c) Metal turning (d) Hardness

RRB JE 21-12-2014 (08 Green Paper)

Ans : (d)Brinell hardness test–The Brinell hardness number (BHN) is obtained by dividing the applied force by the spherical surface area of the indentation.

$$B.H.N. = \frac{\text{Applied load in kg}}{\text{Area of impression or indentation in mm}}$$



23. Which of the following surface hardening processes needs no quenching?

(a) Induction hardening (b) Flame hardening
(c) Nitriding (d) Case carburising

RRB JE 30-08-2019 (Shift-I)

Ans : (c) Nitriding–Nitriding surface hardening is a process with nitrogen to the surface element of diffusion solution on metal/steel and cast iron ferritic, by mean iron at temperature below the critical temperature (between 500-590ºC) for a period of time in contact with a gas or liquid nitrogen.

- To obtain high surface hardness.
- To improve fatigue life.
- To improve corrosion resistance (except for stainless steels)
- To increase wear resistance and antigalling properties.

24. The lower critical point for all steels is–

(a) 600^{o}C (b) 723^{o}C
(c) 800^{o}C (d) 913^{o}C

RRB JE CBT-II 31.08.2019 IInd Shift
RRB SSE 04-09-2015 (Shift-II)

Ans :(b) The lower critical point for all steels is 723^{0}C. At this temperature, birth of new grains take place.

- Lower critical point →The temperature point at which the change starts on heating.
- Upper critical point →The temperature point where this change ends on heating.

25. In which of the following process does mild steel absorb carbon and nitrogen to obtain a hard surface?

(a) Carburizing (b) Cyaniding
(c) Nitriding (d) Annealing

RRB-JE 30.08.2019, Ist Shift

Ans. (b) : Cyaniding is a process of hardening the surface of steel components through the addition of nitrogen and carbon.

- It is done by immersing the work piece in a bath of molten sodium cyanide and sodium carbonate.
- This process is conducted at a temperature of 950^{0}C.

26. Age hardening is related to:

(a) silver (b) duralumin
(c) brass (d) copper

RRB SSE: 04-09-2015 (Shift-II)

Ans : (b) Age hardening is a heat treatment technique used to increase the yield strength of malleable materials, including most structural alloys of aluminimum, magnesium, nickel and its alloy (such as duralumin) and some types of steel.

27. Chilled cast iron is produced–

(a) By adding magnesium to molten cast iron
(b) By quick cooling of molten cast iron
(c) From white cast iron by annealing process
(d) All of the options

RRB JE CBT-II 31.08.2019 IInd Shift

Ans :(b) Chilled cast iron is a white cast iron produced by quick cooling of molten iron.

- The quick cooling is generally called chilling and the iron produced is known as chilled cast iron.
- Nodular cast iron is produced by adding magnesium to molten cast iron.
- Malleable cast iron is produced from white cast iron by annealing process.

28. Which of the following phase is obtained as the end product, after complete heat treatment cycle in austempering process?

(a) Pearlite (b) Bainite
(c) Martensite (d) Austenite

RRB JE CBT-II 31.08.2019 IInd Shift

Ans :(b) Austempering is a process of tempering in which steel is heated, above the upper critical temperature, at about 875^0C where the structure consists entirely of austenite. It is then suddenly cooled by quenching it in a salt bath or lead bath maintained at a temperature of about 250^0C to 525^0C, so as to facilitate the transformation of austenite into bainite.

- So the bainite is obtained as the end product, after complete heat treatment cycle in austempering process.

29. ..... is formed when martensite is warmed to about 400°C.

(a) Pearlite (b) Austenite
(c) Troosite (d) Bainite

RRB-JE 30.08.2019, Ist Shift

Ans. (c) : Troosite is formed when martensite is warmed to about 400^0C.

- It is lower in hardness and brittleness than martensite.

30. Which of the following is the hardest constituent of steel?

(a) Ledeburite (b) Austenite
(c) Martensite (d) Bainite

RRB-JE 29.08.2019, Ist Shift

Ans. (c) : Martensite is a very hard form of steel crystalline structure.

- Martensite is formed in carbon steels by rapid cooling (quenching) of the austenite form of iron.
- The highest hardness of a pearlitic steel is 400 Brinell, where asmartensite can achieve 700 Brinell.

31. Which of the following processes permits the transformation of austenite to martensite, throughout the cross–section of a component without cracking or distortion?

(a) Tempering (b) Annealing
(c) Austempering (d) Martempering

RRB JE CBT-II 31.08.2019 IInd Shift

Ans :(d) Martempering is a process of tempering in which steel is heated above the upper critical point and then quenched so that it is in the upper martensite range.

Hence, martempering process permits the transformation of austenite to martensite, throughout the cross-section of a component without cracking or distortion.

32. Cyaniding is carried out at a temperature of .....

(a) 300^oC (b) 500^oC
(c) 950^oC (d) 175^oC

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (c) The Cyaniding is a case of surface hardening process in which both carbon and nitrogen are absorbed by the metal surface to get it hardened.

- Cyaniding is carried out at a temperature of 950^0C .
- In this process, the piece of low carbon steel is immersed in a both of cyanide salt, such as sodium cyanide or potassium cyanide maintained at 850^0C to 950^0C.
- This process is mainly applied to the low carbon steel parts of automobiles.

33. The temperature point at which the change starts on heating the steel is called–

(a) Point of recalescence
(b) Point of decalescence
(c) Lower critical point
(d) Upper critical point

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (c) The temperature point at which the change starts on heating the steel is called lower critical point.

- For all steels L.C.P. = 723^0C
- U.C.P. = At this point change ends on heating the steel.

34. Which carburising method has high production rate?

(a) Solid powder carburising
(b) Liquid carburising
(c) Pack carburising
(d) Gas carburising

RRB JE CBT-II 31.08.2019 IInd Shift

Ans : (d) Carburising is the process of case hardening which is applied to low carbon steel up to 0.18% carbon.

- In this process steel is held at a temperature of 870^0C to 925^0C.
- Gas carburising method has high production rate. In this method CH_4, C_2H_6 or C_3H_8 are used.

35. The diffusing hardening element in case of the carburizing process is-

(a) Nickel (b) Manganese
(c) Chromium (d) Carbon

RRB-JE 30.08.2019, Ist Shift

Ans. (d) : The diffusing hardening element in case of the carburizing process is carbon.

- This is carried out for low carbon steel which do not respond readily to quenching process because of the very low carbon content.
- The amount of carbon diffused into steel depends on the carburising temperature and time.