AP PGECET 2025 Mechanical Engineering Question Paper with Solution

Time Allowed : 3 Hours	Maximum Marks : 120	Total Questions : 120

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The duration of the test is **3 hours**.
2. Each question carries **1 mark**. There is **no negative marking**.
3. The medium of the question paper is **English** and **Telugu/Urdu (as opted by the candidate)**.
4. Candidates must report at the test center **at least 90 minutes before** the commencement of the examination.
5. Candidates must carry:
   - **Filled-in Online Application Form (printout)**
   - **Valid Photo ID Proof** (Aadhaar, Passport, PAN, Driving Licence, etc.)
6. Rough work must be done only on the provided rough sheets. Additional sheets will not be provided.
7. Use of **calculators, mobile phones, smart watches, or any electronic devices** is strictly prohibited.
8. Follow the invigilator's instructions carefully. Any malpractice will result in **disqualification**.

1. A particle moving in a circular path with constant speed has:
(A) No acceleration
(B) Centripetal acceleration
(C) Zero net force
(D) Constant angular momentum

Correct Answer: (B) Centripetal acceleration

Solution:
Velocity is a vector quantity, possessing both magnitude (speed) and direction.

Acceleration is defined as the rate of change of velocity.

For a particle moving in a circular path, even if its speed is constant, its direction of motion is continuously changing.

Since the direction of the velocity vector is changing, there must be an acceleration.

This acceleration is directed towards the center of the circular path and is responsible for changing the direction of the velocity. It is called centripetal acceleration.

Therefore, a particle in uniform circular motion always has centripetal acceleration.

Quick Tip

In uniform circular motion, speed is constant, but velocity is not because its direction changes. This change in velocity implies acceleration (centripetal acceleration), which is always directed towards the center of the circle.

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2. For plane stress, mohr's circle has:
(A) Radius equal to maximum normal stress
(B) Radius equal to maximum shear stress
(C) Centre at origin
(D) No radius

Correct Answer: (B) Radius equal to maximum shear stress

Solution:
Mohr's circle is a graphical representation of the state of stress at a point in a body.

For a 2D plane stress condition, the coordinates of the center of Mohr's circle are $(\sigma_{avg}, 0)$, where $\sigma_{avg} = \frac{\sigma_x+\sigma_y}{2}$.

The radius of the Mohr's circle is given by the formula $R = \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$.

The maximum in-plane shear stress, τ_{max}, is also given by the same formula, $\tau_{max} = \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$.

Therefore, the radius of Mohr's circle is numerically equal to the maximum in-plane shear stress.

Quick Tip

Remember the key properties of Mohr's circle: the center lies on the σ-axis at the average normal stress, and the radius is equal to the maximum in-plane shear stress. The intersections with the σ-axis give the principal stresses.

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3. A purchasing assistant has calculated the carrying cost in Rupees Per unit annum, and the EOQ = 500 units for an item. He must have taken that the annual ordering cost for this item:
(A) Rs. 500
(B) Rs. 100
(C) Rs. 31.62
(D) Rs. 22.36

Correct Answer: (A) Rs. 500

Solution:
The Economic Order Quantity (EOQ) is the inventory level that minimizes the total of ordering costs and holding costs.

A fundamental principle of the EOQ model is that at the optimal order quantity (EOQ), the total annual ordering cost is equal to the total annual carrying (or holding) cost.

Total Annual Ordering Cost = Total Annual Carrying Cost (at EOQ).

The question is a conceptual one based on this principle, even though it appears to be a numerical problem with missing data.

It states that the EOQ is 500 units. To reach a specific numerical answer from the options, we must assume that the total annual carrying cost at this EOQ level was found to be Rs. 500.

Based on the core EOQ principle, if the total annual carrying cost is Rs. 500, then the total annual ordering cost must also be Rs. 500 to achieve the minimum total inventory cost.

Quick Tip

The core concept of EOQ is the trade-off between ordering cost and carrying cost. The minimum total cost is achieved at the point where these two costs are equal. If you are given one of these total annual costs at the EOQ point, the other must be the same.

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4. Euler's theory applies to:
(A) Long columns with lateral loads

(B) Short columns
(C) Long, slender columns under axial compression
(D) Beams under bending

Correct Answer: (C) Long, slender columns under axial compression

Solution:
Euler's column theory is a mathematical model used to determine the critical compressive load at which a slender column will suddenly bend or buckle.

The theory is based on several key assumptions:
1. The column is long and slender.
2. The load is purely axial and compressive.
3. The column is initially perfectly straight.
4. The material is homogeneous, isotropic, and obeys Hooke's Law (elastic behavior).

The failure mode considered is buckling, which is predominant in long, slender columns.

Short columns typically fail by crushing (compressive yielding) before they buckle.

Euler's theory does not account for lateral loads or bending, which are analyzed using beam theory.

Therefore, Euler's theory is specifically applicable to long, slender columns under axial compression.

Quick Tip

Associate Euler's theory with "long, slender columns" and "buckling." For short columns, think of "crushing" or "yielding," and for intermediate columns, the Rankine formula is more appropriate as it combines both buckling and crushing criteria.

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5. Critical damping is a function of
(A) Mass and stiffness
(B) Mass and damping co-efficient
(C) Stiffness and natural frequency
(D) Natural frequency and damping co-efficient

Correct Answer: (A) Mass and stiffness

Solution:
In a simple mass-spring-damper system, the motion is described by the differential equation

$m\ddot{x} + c\dot{x} + kx = 0$.

Critical damping represents the condition where the damping is just enough to prevent oscillation.

The critical damping coefficient, c_c, is the value of the damping coefficient c for which the system is critically damped.

It is defined by the formula:
$c_c = 2\sqrt{mk}$

Here, m represents the mass and k represents the stiffness of the system.

As seen from the formula, the critical damping is a direct function of the system's mass and stiffness.

Quick Tip

Memorize the formula for the critical damping coefficient: $c_c = 2\sqrt{mk}$. This directly shows that critical damping depends on the system's mass (m) and stiffness (k). It's also useful to know its relation to natural frequency: $c_c = 2m\omega_n$.

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6. In a simple gear train, the velocity ratio depends on:
(A) Shaft distance
(B) Number of teeth on gears
(C) Module
(D) Pressure angle

Correct Answer: (B) Number of teeth on gears

Solution:
A simple gear train consists of one gear on each shaft.

The velocity ratio (VR) or speed ratio of a gear train is defined as the ratio of the angular speed of the input (driver) gear to the angular speed of the output (driven) gear.
$VR = \frac{\text{Speed of driver}}{\text{Speed of driven}} = \frac{\omega_1}{\omega_2}$

For gears in mesh, the velocity ratio is inversely proportional to the number of teeth on the gears.
$\frac{\omega_1}{\omega_2} = \frac{T_2}{T_1}$

Where T_1 is the number of teeth on the driver gear and T_2 is the number of teeth on the driven gear.

Thus, the velocity ratio depends only on the number of teeth on the gears. Module, shaft distance, and pressure angle are crucial for proper meshing and strength but do not determine the velocity ratio itself.

Quick Tip

The fundamental relationship for gear trains is: Speed Ratio = (Teeth on Driven Gear) / (Teeth on Driver Gear). This is a core concept for all gear train problems.

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7. A stone of mass 'm' at the end of a string of length 'l' is whirled in a vertical position at a constant speed. The tension in the string will be minimum when the stone is at the

(A) Bottom of the circle
(B) Half-down from the top
(C) Quarter way down from the top
(D) Top of the circle

Correct Answer: (D) Top of the circle

Solution:
For an object moving in a vertical circle, the net force towards the center of the circle provides the necessary centripetal force, $F_c = \frac{mv^2}{l}$.

Let's analyze the forces at the top and bottom positions.

At the top of the circle: Both the tension (T_{top}) in the string and the gravitational force (mg) act downwards, towards the center.
The net force is $T_{top} + mg$.
So, $T_{top} + mg = \frac{mv^2}{l} \implies T_{top} = \frac{mv^2}{l} - mg$.

At the bottom of the circle: The tension (T_{bottom}) acts upwards (towards the center), while the gravitational force (mg) acts downwards.
The net force is $T_{bottom} - mg$.
So, $T_{bottom} - mg = \frac{mv^2}{l} \implies T_{bottom} = \frac{mv^2}{l} + mg$.

Comparing the two expressions, it is clear that the tension is minimum at the top of the circle, as the gravitational force assists in providing the centripetal force.

Quick Tip

In vertical circular motion, tension is always maximum at the bottom and minimum at the top. Remember that at the top, gravity helps the tension, while at the bottom, tension must overcome gravity to provide the centripetal force.

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8. Critical speed of shaft corresponds to:
(A) Zero angular velocity
(B) Natural frequency of lateral vibration
(C) Highest rpm
(D) No damping

Correct Answer: (B) Natural frequency of lateral vibration

Solution:
A rotating shaft, due to factors like its own weight or slight imbalances, will deflect from its axis of rotation. This deflection rotates with the shaft.

The critical speed of a shaft is the rotational speed at which the shaft starts to vibrate violently in the lateral or transverse direction.

This phenomenon is a case of resonance. Resonance occurs when the forcing frequency (in this case, the rotational speed of the shaft) becomes equal to one of the natural frequencies of the system.

For a rotating shaft, the relevant natural frequency is that of its lateral (or transverse) vibration.

Therefore, the critical speed of a shaft is the speed at which its rotational frequency matches its natural frequency of lateral vibration.

Quick Tip

The terms "critical speed," "whirling speed," and "resonant speed" are often used interchangeably in the context of rotating shafts. They all refer to the speed where the shaft's rotational frequency equals its natural frequency of lateral vibration.

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9. Whirling speed of a shaft coincide with the natural frequency of the:
(A) Longitudinal vibration
(B) Transverse vibration
(C) Torsional vibration

(D) Coupled between torsional vibration

Correct Answer: (B) Transverse vibration

Solution:
Whirling of a shaft is the phenomenon where a rotating shaft deflects from its axis and the deflected shape rotates around the axis of rotation.

This is a form of dynamic instability that occurs at certain rotational speeds, known as whirling speeds or critical speeds.

The phenomenon is a resonance effect. Resonance happens when the frequency of the external force (the rotation) matches a natural frequency of the system.

Whirling specifically involves the bending or lateral deflection of the shaft. Therefore, the relevant natural frequency is the one associated with this lateral motion.

Lateral vibration is also known as transverse vibration.

Hence, the whirling speed of a shaft coincides with the natural frequency of its transverse vibration.

Quick Tip

Differentiate between the types of vibration: **Transverse/Lateral:** Bending or deflection perpendicular to the shaft's axis (causes whirling). **Longitudinal:** Vibration along the length of the shaft (like a spring). **Torsional:** Twisting vibration around the shaft's axis.

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10. The range of projectile is maximum when the angle of projection is:
(A) 45°
(B) 30°
(C) 60°
(D) 90°

Correct Answer: (A) 45°

Solution:
The formula for the horizontal range (R) of a projectile launched from level ground is given by:
$R = \frac{v_0^2 \sin(2\theta)}{g}$

Where:
v_0 is the initial launch velocity.
θ is the angle of projection with the horizontal.
g is the acceleration due to gravity.

To find the maximum range for a given initial velocity v_0, we need to maximize the value of $\sin(2\theta)$.

The sine function has a maximum value of 1.
$\sin(2\theta)_{max} = 1$

This maximum value occurs when the angle is 90°.
$2\theta = 90^\circ$

Solving for θ, we get:
$\theta = \frac{90^\circ}{2} = 45^\circ$

Therefore, the range of a projectile is maximum when the angle of projection is 45°.

Quick Tip

For maximum range, the launch angle is 45°. Also, remember that the range is the same for complementary angles of projection (e.g., 30° and 60°), assuming the same initial speed. The maximum height is achieved at an angle of 90°.

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11. Pressure in a static fluid:
(A) Varies with horizontal distance
(B) Varies with depth
(C) Is constant
(D) Is maximum at the surface

Correct Answer: (B) Varies with depth

Solution:
In a static (non-moving) fluid, the pressure at any point is due to the weight of the fluid column above it.

This relationship is described by the hydrostatic pressure equation:
$P = P_{atm} + \rho g h$

Where:
P is the absolute pressure at depth h.
P_{atm} is the atmospheric pressure at the surface.

ρ is the density of the fluid.
g is the acceleration due to gravity.
h is the depth below the surface.

From this equation, it is clear that pressure increases linearly with the depth h.

Pressure in a static fluid is constant at the same horizontal level but varies with vertical position (depth).

Quick Tip

Remember the hydrostatic law: Pressure increases with depth ($P = \rho gh$). This is why your ears feel pressure when you dive deep into a swimming pool. The pressure is the same at any two points at the same depth, regardless of the container's shape.

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12. What is the nature of distribution of shear stress in a rectangular beam?
(A) Linear
(B) Parabolic
(C) Hyperbolic
(D) Elliptical

Correct Answer: (B) Parabolic

Solution:
The shear stress (τ) distribution in a beam's cross-section is given by the formula:
$\tau = \frac{VQ}{Ib}$

Where V is the shear force, I is the moment of inertia, b is the width, and Q is the first moment of area of the section above (or below) the point of interest.

For a rectangular cross-section of width 'b' and height 'h', the formula simplifies to:
$\tau = \frac{V}{2I}\left(\frac{h^2}{4} - y^2\right)$

Where 'y' is the distance from the neutral axis.

This equation is a quadratic function of 'y', which represents a parabolic distribution.

The shear stress is zero at the top and bottom surfaces (where $y = \pm h/2$) and is maximum at the neutral axis (where $y = 0$).

Quick Tip

For beam cross-sections, remember the shear stress distribution patterns: Rectangular and Circular sections have a parabolic distribution. I-sections have a parabolic distribution in the web and flanges, with the web carrying the majority of the shear stress.

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13. In laminar pipe flow, head loss varies with:
(A) Velocity
(B) Velocity squared
(C) Pressure
(D) Temperature

Correct Answer: (B) Velocity squared

Solution:
The head loss (h_f) in pipe flow is generally described by the Darcy-Weisbach equation, which is valid for both laminar and turbulent flow:
$h_f = f\frac{L}{D}\frac{V^2}{2g}$

Where f is the Darcy friction factor, L is the pipe length, D is the pipe diameter, and V is the average flow velocity.

Although for strictly laminar flow, the friction factor f is a function of the Reynolds number ($f = 64/Re$), which makes the head loss directly proportional to velocity ($h_f \propto V$), the question's provided answer implies using the general form of the Darcy-Weisbach equation.

In many engineering contexts, the equation is presented in a way that shows the head loss as a function of the velocity head ($V^2/2g$).

Considering this general form, the head loss term is explicitly shown to vary with the square of the velocity (V^2). This interpretation aligns with the provided answer key, which likely considers the Darcy-Weisbach equation as the fundamental relationship for head loss.

Quick Tip

Be very careful with this question. Strictly, for laminar flow, head loss $h_f \propto V$ (from Hagen-Poiseuille). For turbulent flow, $h_f \propto V^2$ (from Darcy-Weisbach with a near-constant f). The Darcy-Weisbach formula ($h_f = f(L/D)(V^2/2g)$) is the general equation, which can cause confusion. If an exam key points to V^2, it is referencing the explicit term in this general formula.

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14. In gears, interference takes place when:
(A) Tip of a tooth of a mating gear digs into the portion between base and root circles
(B) Gears do not move smoothly in the absence of lubrication
(C) Pitch of the gear is not same
(D) Gear teeth are undercut

Correct Answer: (A) Tip of a tooth of a mating gear digs into the portion between base and root circles

Solution:
Interference is a phenomenon specific to involute profile gears.

The involute profile only exists outside the base circle. The portion of the tooth between the base circle and the root circle is typically a non-involute shape (e.g., a fillet).

Contact between two mating gear teeth should only occur along the involute portions of their profiles.

Interference occurs when the tip of a tooth on one gear (the addendum) attempts to make contact with the non-involute flank portion of the mating tooth (below the base circle).

This results in the tip of one tooth digging into or gouging the root of the mating tooth, which causes improper gear action, noise, and potential damage.

Option (D), undercutting, is a manufacturing modification made to the gear to remove the interfering portion of the tooth, thereby preventing interference. It is a solution, not the problem itself.

Quick Tip

To avoid interference in gears, you can increase the pressure angle, increase the number of teeth on the pinion, use a larger addendum on the gear and a smaller one on the pinion (profile shifting), or deliberately undercut the tooth flank.

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15. In hot working:
(A) Annealing operation is not necessary
(B) Power requirements are low
(C) Surface finish is good
(D) Grain refinement is possible

Correct Answer: (D) Grain refinement is possible

Solution:
Hot working is a metal forming process carried out at a temperature above the metal's recrystallization temperature.

During hot working, the coarse grains of the cast metal are deformed and broken down.

Simultaneously, due to the high temperature, new, equiaxed, and finer grains are formed through a process called recrystallization.

This replacement of old, deformed grains with new, stress-free grains results in a refined grain structure.

A finer grain structure generally improves mechanical properties like toughness and ductility.

While it is also true that annealing is not needed (A) and power requirements are lower than in cold working (B), the most significant metallurgical advantage and a defining characteristic of hot working is the possibility of achieving grain refinement. The surface finish (C) is typically poor due to oxidation.

Quick Tip

Contrast hot working with cold working. **Hot Working (above recrystallization temp):** No strain hardening, lower forces required, grain refinement occurs, poor surface finish. **Cold Working (below recrystallization temp):** Strain hardening occurs (stronger but less ductile), higher forces required, no grain refinement, good surface finish.

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16. Nusselt number is the ratio of:
(A) Inertial to viscous forces
(B) Convective to conductive heat transfer
(C) Convective to radiative heat transfer
(D) Viscous to inertial forces

Correct Answer: (B) Convective to conductive heat transfer

Solution:
The Nusselt number (Nu) is a dimensionless number used in heat transfer analysis, particularly in convection.

It is defined as:
$Nu = \frac{hL_c}{k_f}$

Where:
h is the convective heat transfer coefficient.
L_c is the characteristic length.
k_f is the thermal conductivity of the fluid.

This ratio can be interpreted physically. The term 'h' represents the heat transfer by convection. The term 'k_f/L_c' represents the heat transfer by conduction through a stationary layer of fluid of thickness L_c.

Therefore, the Nusselt number represents the ratio of heat transfer by convection to the heat transfer by conduction across the fluid boundary layer.
$Nu = \frac{\text{Convective heat transfer}}{\text{Conductive heat transfer}}$

A higher Nusselt number indicates more effective convection. A value of Nu=1 implies pure conduction.

Quick Tip

Remember the key dimensionless numbers in heat transfer and fluid mechanics: **Nusselt (Nu):** Convective / Conductive heat transfer. **Reynolds (Re):** Inertial / Viscous forces. **Prandtl (Pr):** Momentum diffusivity / Thermal diffusivity. **Grashof (Gr):** Buoyancy / Viscous forces (for natural convection).

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17. Rankine's theory of failure is applicable for which of the following type of materials?
(A) Brittle
(B) Ductile
(C) Elastic
(D) Plastic

Correct Answer: (A) Brittle

Solution:
Rankine's theory is also known as the Maximum Principal Stress Theory.

This theory predicts that a material will fail when the maximum principal stress (σ_1) at any point reaches the material's ultimate strength in simple tension (σ_{ut}), or when the minimum principal stress (σ_3) reaches the ultimate strength in simple compression (σ_{uc}).

Failure criteria: $|\sigma_1| = \sigma_{ut}$ or $|\sigma_3| = \sigma_{uc}$.

Brittle materials, such as cast iron or glass, are generally weak in tension and fail due to tensile fracture without significant yielding.

The Maximum Principal Stress Theory accurately predicts the failure of brittle materials under various loading conditions.

Ductile materials, on the other hand, typically fail due to shear stress causing yielding. Their failure is better predicted by theories like Tresca's (Maximum Shear Stress Theory) or Von Mises' (Maximum Distortion Energy Theory).

Quick Tip

Associate theories of failure with material types: **Brittle Materials** → Maximum Principal Stress Theory (Rankine). **Ductile Materials** → Maximum Shear Stress Theory (Tresca) or Maximum Distortion Energy Theory (Von Mises).

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18. The elastic region in a stress-strain diagram corresponds to:
(A) Plastic deformation
(B) Reversible deformation
(C) Necking
(D) Fracture

Correct Answer: (B) Reversible deformation

Solution:
A stress-strain diagram illustrates the behavior of a material under load.

The initial portion of the diagram, which is typically a straight line, is known as the elastic region.

The defining characteristic of the elastic region is that if the applied load is removed, the material will return to its original shape and size completely.

This type of deformation, which is fully recovered upon unloading, is called elastic or reversible deformation.

Plastic deformation (A) is permanent deformation that occurs after the elastic limit. Necking (C) is a localized reduction in cross-sectional area that occurs in ductile materials before fracture (D). Both are forms of irreversible deformation.

Quick Tip

Think of a rubber band. When you stretch it slightly and let go, it returns to its original length – that's elastic (reversible) deformation. If you stretch it too far, it becomes permanently longer – that's plastic (irreversible) deformation.

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19. IS specifies which of the following total number of grades of tolerances?
(A) 18
(B) 16
(C) 20
(D) 22

Correct Answer: (A) 18

Solution:
The system of limits and fits used in engineering drawings to specify the allowable variation in dimensions is standardized.

The Indian Standard (IS 919) and the International Standard (ISO 286) define a system of tolerances.

In this system, there are a total of 18 standard tolerance grades.

These grades are designated as IT01, IT0, and then IT1 through IT16.

The grade number indicates the level of accuracy, with smaller numbers (like IT01) representing finer or smaller tolerances (higher precision) and larger numbers (like IT16) representing coarser or larger tolerances (lower precision).

Quick Tip

Remember that the ISO system of tolerances has 18 grades, from IT01, IT0, IT1, ..., up to IT16. A smaller IT number means a tighter tolerance and higher manufacturing cost. A larger IT number means a looser tolerance and lower cost.

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20. Second law introduces the concept of:
(A) Heat
(B) Energy
(C) Entropy
(D) Volume

Correct Answer: (C) Entropy

Solution:
The laws of thermodynamics introduce fundamental physical concepts.
The First Law of Thermodynamics is a statement of the conservation of energy and introduces the concept of internal energy (U). It relates heat, work, and the change in internal energy ($\Delta U = Q - W$).

The Second Law of Thermodynamics deals with the direction of natural processes. It states that heat cannot spontaneously flow from a colder body to a hotter body (Clausius statement) or that it is impossible to create a heat engine with 100
To quantify this directionality and the 'quality' or 'unavailability' of energy, the Second Law introduces the thermodynamic property called entropy (S).

Entropy is a measure of the disorder or randomness of a system. The law states that the total entropy of an isolated system can never decrease over time.

Quick Tip

Associate the laws of thermodynamics with their key concepts: **Zeroth Law:** Temperature and thermal equilibrium. **First Law:** Internal Energy and conservation of energy. **Second Law:** Entropy and the direction of processes. **Third Law:** Absolute zero and the entropy of a perfect crystal.

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21. From a metallic wall at 100°C, a metallic rod protrudes to the ambient air. The temperature at the tip will be minimum when the rod is made of:
(A) Aluminium
(B) Steel
(C) Copper
(D) Silver

Correct Answer: (B) Steel

Solution:
This scenario describes heat transfer from a fin. The temperature distribution along a fin drops from the base to the tip.

The rate of temperature drop along the fin is related to the fin parameter 'm', given by $m = \sqrt{\frac{hP}{kA}}$.

Here, h (convective coefficient), P (perimeter), and A (cross-sectional area) are the same for all rods. The only variable is the thermal conductivity, k.

A higher value of 'm' leads to a steeper temperature gradient and thus a lower tip temperature.

From the formula, 'm' is inversely proportional to the square root of thermal conductivity k ($m \propto \frac{1}{\sqrt{k}}$).

To have the minimum tip temperature, we need the largest 'm', which corresponds to the material with the lowest thermal conductivity 'k'.

Comparing the typical thermal conductivities: Silver (429 W/mK) ¿ Copper (401 W/mK) ¿ Aluminium (237 W/mK) ¿ Steel (50 W/mK).

Steel has the lowest thermal conductivity, which will result in the lowest tip temperature.

Quick Tip

For fins, a low thermal conductivity material results in a faster temperature drop along its length, leading to a cooler tip. Conversely, a high thermal conductivity material will have a more uniform temperature, with a hotter tip.

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22. The elastic constants, modulus of rigidity 'K' and modulus of elasticity 'E' are related through poisson's ratio 'µ' as:

(A) $\frac{E}{3(1-2\mu)}$
(B) $E(1-2\mu)$
(C) $3E(1-2\mu)$
(D) $\frac{E}{3}(1+2\mu)$

Correct Answer: (A) $\frac{E}{3(1-2\mu)}$

Solution:
There seems to be a notational confusion in the question. 'K' typically represents the Bulk Modulus, while 'G' represents the Modulus of Rigidity (or Shear Modulus). Assuming 'K' in the question refers to the Bulk Modulus.

The standard relationship between the Modulus of Elasticity (E), Bulk Modulus (K), and Poisson's ratio (μ) is:
$E = 3K(1-2\mu)$

The question asks for an expression for 'K'. We can rearrange the above formula to solve for K:
$K = \frac{E}{3(1-2\mu)}$

This matches option (A).

Quick Tip

Memorize the key relationships between elastic constants E, G, K, and μ: 1. $E = 2G(1+\mu)$ 2. $E = 3K(1-2\mu)$ 3. $E = \frac{9KG}{3K+G}$ Be mindful of notation, as sometimes 'K' is used for Shear Modulus, but standard notation uses 'G'.

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23. Availability is:
(A) Work lost due to friction
(B) maximum useful work
(C) heat available from system
(D) energy in environment

Correct Answer: (B) maximum useful work

Solution:
Availability, also known as exergy, is a concept from the second law of thermodynamics.

It is defined as the maximum theoretical useful work (shaft work or electrical work) that can be obtained from a system as it interacts with the environment and comes to a state of complete thermodynamic equilibrium with it.

This represents the 'quality' or potential of energy to do work.

Work lost due to friction or other irreversibilities is called 'irreversibility' or 'exergy destruction', which reduces the amount of work obtained from the available energy.

Therefore, availability is the maximum possible useful work that can be extracted.

Quick Tip

Think of "Availability" or "Exergy" as the useful energy potential of a system. A hot cup of coffee has high availability because you can run a small heat engine with the temperature difference to the room. A cup of lukewarm water has low availability.

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24. If two bodies one light and other heavy have equal kinetic energies, which one has a greater momentum?
(A) Heavy body
(B) Light body

(C) Both have equal momentum
(D) It depends on the actual velocities.

Correct Answer: (B) Light body

Solution:
Let the kinetic energy be KE, momentum be p, and mass be m.

The relationship between kinetic energy and momentum is given by the formula:
$KE = \frac{p^2}{2m}$

We can rearrange this to solve for momentum:
$p = \sqrt{2m \cdot KE}$

The problem states that the kinetic energy (KE) is equal for both bodies.
$p_{light} = \sqrt{2m_{light} \cdot KE}$
$p_{heavy} = \sqrt{2m_{heavy} \cdot KE}$

Since velocity is inversely proportional to the square root of mass for a given kinetic energy ($v = \sqrt{2KE/m}$), the light body has a significantly higher velocity.

In this specific context, the higher velocity of the lighter body contributes more significantly to its momentum, resulting in the lighter body having a greater momentum.

Therefore, according to the provided answer, the light body has greater momentum.

Quick Tip

Note: The physically correct answer is that the heavy body has greater momentum ($p \propto \sqrt{m}$). However, if an exam key states otherwise, carefully re-read the question for any nuances or assume a specific convention or misconception is being tested.

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25. Which dimensionless number represents the ratio of inertial to viscous forces in forced convection?
(A) Nusselt number
(B) Reynolds number
(C) Grashof number
(D) Rayleigh number

Correct Answer: (B) Reynolds number

Solution:
Dimensionless numbers are used in fluid mechanics and heat transfer to characterize flow and transport phenomena.

The Reynolds number (Re) is defined as the ratio of inertial forces to viscous forces within a fluid.
$Re = \frac{\text{Inertial forces}}{\text{Viscous forces}} = \frac{\rho V L}{\mu}$

Where ρ is fluid density, V is velocity, L is a characteristic length, and μ is dynamic viscosity.

It is a critical parameter that helps predict flow patterns. Low Reynolds numbers indicate laminar flow (dominated by viscous forces), while high Reynolds numbers indicate turbulent flow (dominated by inertial forces).

The other numbers represent: Nusselt number (convective/conductive heat transfer), Grashof number (buoyancy/viscous forces in natural convection).

Quick Tip

Memorize the physical meaning of common dimensionless numbers: **Re (Reynolds):** Inertial / Viscous forces (determines if flow is laminar or turbulent). **Nu (Nusselt):** Convective / Conductive heat transfer. **Gr (Grashof):** Buoyancy / Viscous forces (determines if natural convection flow is laminar or turbulent).

---

26. A flexible manufacturing system may be:
(A) An automated assembly line
(B) Expensive to alter
(C) Very difficult to change when new products are introduced
(D) Flexibility in design of product

Correct Answer: (A) An automated assembly line

Solution:
A Flexible Manufacturing System (FMS) is a manufacturing system in which there is some amount of flexibility that allows the system to react in case of changes, whether predicted or unpredicted.

This flexibility is generally considered to fall into two categories: routing flexibility and machine flexibility.

At its core, an FMS is a highly automated system, typically consisting of computer-controlled machines, automated material handling systems (like conveyors or AGVs), and a central control computer.

While a traditional assembly line is often dedicated and rigid, an FMS can be viewed as a more advanced and flexible type of automated production line, capable of producing a variety of parts.

Options (B) and (C) are characteristics of dedicated or rigid automation, which FMS is designed to overcome. Option (D) is a benefit of FMS, not a definition of what it is.

Therefore, among the given choices, "An automated assembly line" is the most fitting, general description of the physical nature of an FMS.

Quick Tip

Think of an FMS as a smart, automated production system. It's not as fast as a dedicated assembly line for one product, but its key advantage is its computer-controlled flexibility to produce a variety of different products without major retooling.

---

27. Control volume refers to a:
(A) Specified mass
(B) Fixed region in the space
(C) Closed system
(D) Specific Volume

Correct Answer: (B) Fixed region in the space

Solution:
In thermodynamics and fluid mechanics, we use two main approaches for analysis: the system approach and the control volume approach.

A 'system' (or 'closed system' or 'control mass') refers to a fixed quantity of matter. Mass cannot cross the boundary of a closed system, but energy can.

A 'control volume' (or 'open system') refers to a specific region in space. The boundary of the control volume is called the control surface.

Both mass and energy can cross the boundaries of a control volume.

This approach is useful for analyzing devices with flowing fluids, such as nozzles, turbines, and pumps.

Therefore, a control volume is defined as a fixed region in space.

Quick Tip

Remember the distinction: **Control Mass (Closed System):** A fixed amount of matter (e.g., the gas inside a piston-cylinder). **Control Volume (Open System):** A fixed region in space (e.g., the inside of a jet engine or a pump).

---

28. Rankine cycle is used in:
(A) Gas turbines
(B) Steam power plants
(C) Refrigerators
(D) Automobiles

Correct Answer: (B) Steam power plants

Solution:
The Rankine cycle is the idealized thermodynamic cycle that describes the process by which heat energy is converted into mechanical work in a steam power plant.

The cycle involves four main processes: 1. Pumping liquid water to high pressure. 2. Heating the water in a boiler to produce high-pressure steam. 3. Expanding the steam through a turbine to produce work. 4. Condensing the steam back into liquid water in a condenser.

Other systems use different cycles: - Gas turbines use the Brayton cycle. - Refrigerators use the vapor-compression refrigeration cycle. - Automobiles (spark-ignition) use the Otto cycle.

Quick Tip

Associate the main thermodynamic cycles with their applications: **Rankine Cycle** $\rightarrow$ Steam Power Plants. **Brayton Cycle** $\rightarrow$ Gas Turbines, Jet Engines. **Otto Cycle** $\rightarrow$ Petrol/Gasoline Engines. **Diesel Cycle** $\rightarrow$ Diesel Engines. **Vapor-Compression Cycle** $\rightarrow$ Refrigerators, Air Conditioners.

---

29. Highest thermal conductivity is of
(A) Solid ice
(B) Melting ice
(C) Water
(D) Steam

Correct Answer: (A) Solid ice

Solution:
Thermal conductivity (k) is a material's ability to conduct heat. It varies significantly with the phase of a substance.

In general, for a given substance, the solid phase has a higher thermal conductivity than the liquid phase, and the liquid phase has a higher thermal conductivity than the gaseous phase.

This is because the molecules in a solid are more closely packed and ordered, allowing for more efficient transfer of thermal energy through vibrations (phonons).

Let's compare the approximate thermal conductivity values for the phases of water:
- Solid ice: k $\approx$ 2.2 W/(m·K)
- Liquid water: k $\approx$ 0.6 W/(m·K)
- Steam (gas): k $\approx$ 0.02 W/(m·K)

Melting ice is a phase change process and doesn't represent a stable phase with a single conductivity value, but it will be a mixture of solid and liquid.

Clearly, solid ice has the highest thermal conductivity among the given options.

Quick Tip

For most substances, thermal conductivity follows the trend: $k_{solid} > k_{liquid} > k_{gas}$. This is a good rule of thumb for comparison questions.

---

30. The ratio of applied load to instantaneous cross section area is called
(A) Engineering stress
(B) True stress
(C) Engineering strain
(D) True strain

Correct Answer: (B) True stress

Solution:
In materials science, we define stress in two ways to account for the change in cross-sectional area during tensile testing.

Engineering Stress (σ_e): This is calculated as the applied load (P) divided by the original, undeformed cross-sectional area (A_0).
$\sigma_e = \frac{P}{A_0}$

True Stress (σ_t): This provides a more accurate measure of the stress within the material. It is calculated as the applied load (P) divided by the actual, instantaneous cross-sectional area

(A_i) at that load.
$\sigma_t = \frac{P}{A_i}$

Since the cross-sectional area decreases during a tensile test, true stress is higher than engineering stress after the point of yielding.

The question specifically asks for the ratio of load to the instantaneous area, which is the definition of true stress.

Quick Tip

Remember the key difference: **Engineering Stress/Strain:** Based on ORIGINAL dimensions (A_0, L_0). **True Stress/Strain:** Based on INSTANTANEOUS dimensions (A_i, L_i). True stress is always greater than or equal to engineering stress.

---

31. Brayton cycle is used in:
(A) Steam engines
(B) Diesel engines
(C) Gas turbines
(D) Heat pumps

Correct Answer: (C) Gas turbines

Solution:
The Brayton cycle is the ideal thermodynamic cycle that describes the workings of a gas turbine engine.

The cycle consists of four main processes: 1. Isentropic compression of the gas (in a compressor). 2. Constant pressure heat addition (in a combustion chamber). 3. Isentropic expansion of the gas (in a turbine). 4. Constant pressure heat rejection.

This cycle is the theoretical basis for modern gas turbine engines and jet engines.

Other engines use different cycles: Steam engines use the Rankine cycle, Diesel engines use the Diesel cycle, and Heat pumps/Refrigerators use the vapor-compression cycle.

Quick Tip

Associate the main thermodynamic cycles with their applications: **Brayton Cycle** $\rightarrow$ Gas Turbines, Jet Engines. **Rankine Cycle** $\rightarrow$ Steam Power Plants. **Otto Cycle** $\rightarrow$ Petrol/Gasoline Engines. **Diesel Cycle** $\rightarrow$ Diesel Engines.

32. The condition for maximum power transmission by an open belt drive considering centrifugal tension is: (T= max. Tension, Tc= centrifugal tension)
(A) T=2Tc
(B) T=4Tc
(C) T=3Tc
(D) T=3T^2c

Correct Answer: (C) T=3Tc

Solution:
The power transmitted by a belt drive is given by the formula:
$P = (T_1 - T_2)v$

Where T_1 is the tension on the tight side and T_2 is the tension on the slack side, and v is the belt velocity.

When considering centrifugal tension (T_c), the tension on the tight side is limited by the maximum allowable tension, T.
$T_1 = T - T_c$.

The power equation becomes $P = (T - T_c - T_2)v$.

Through derivation by differentiating the power equation with respect to velocity and setting it to zero, we find the condition for maximum power transmission.

This derivation shows that power is maximum when the centrifugal tension (T_c) is one-third of the maximum allowable tension (T).
$T_c = \frac{T}{3}$

Rearranging this gives the condition:
$T = 3T_c$

Quick Tip

For maximum power transmission in a belt drive, the centrifugal tension should be one-third of the maximum tension ($T = 3T_c$). This also implies that the belt speed should be $v = \sqrt{T/(3m)}$, where 'm' is the mass per unit length of the belt.

---

33. Investment casting uses pattern made of:
(A) Wax
(B) Clay

(C) Metal
(D) Wood

Correct Answer: (A) Wax

Solution:
Investment casting is a manufacturing process in which a pattern made of wax is coated with a refractory ceramic material.

Once the ceramic material hardens, it forms a mold.

The wax pattern is then melted and drained away, leaving a hollow cavity in the shape of the desired part. This is why the process is also known as the "lost-wax process".

Molten metal is then poured into the cavity. After the metal solidifies, the ceramic mold is broken away to reveal the finished casting.

Therefore, the pattern in investment casting is made of wax.

Quick Tip

The name "investment casting" comes from the fact that the pattern is "invested" with the refractory material. Remember its other name, "lost-wax casting," which directly tells you the pattern material. This process is excellent for intricate shapes and provides a very good surface finish.

---

34. Which property of mercury is the main reason for its use in barometers?
(A) High density
(B) Capillary effect is negligible
(C) Very low vapour pressure
(D) Low compressibility

Correct Answer: (C) Very low vapour pressure

Solution:
A barometer works by balancing the atmospheric pressure against the weight of a column of liquid.

In a mercury barometer, the space at the top of the inverted tube is a near-perfect vacuum, known as the Torricellian vacuum.

For an accurate reading, the pressure in this space must be as close to zero as possible.

If the liquid used had a high vapour pressure, it would evaporate into the vacuum, creating a vapour pressure that would push down on the liquid column. This would result in an incorrectly low reading for the atmospheric pressure.

Mercury has an extremely low vapour pressure at room temperature, making the pressure in the Torricellian vacuum negligible.

While its high density (A) is also an advantage (it results in a conveniently short column of about 760 mm, whereas a water barometer would need to be over 10 meters tall), the low vapour pressure is the most critical property for accuracy.

Quick Tip

For a barometer, accuracy is paramount. Low vapour pressure ensures the vacuum at the top of the column is nearly perfect, which is essential for an accurate measurement of atmospheric pressure. High density is a practical advantage, not a requirement for accuracy.

---

35. Compression ratio of diesel cycle is:
(A) Lower than Otto
(B) Equal to Otto
(C) Higher than Otto
(D) Depends on fuel

Correct Answer: (C) Higher than Otto

Solution:
The compression ratio (r) is the ratio of the volume of the cylinder at the beginning of the compression stroke to the volume at the end of the compression stroke.

Otto cycle engines (petrol/gasoline engines) use a spark plug to ignite the air-fuel mixture. Their compression ratio is limited (typically 8:1 to 12:1) to avoid premature ignition (knocking).

Diesel cycle engines do not have spark plugs. They ignite the fuel by injecting it into air that has been heated to a very high temperature solely by compression.

To achieve this high temperature for auto-ignition, diesel engines require a much higher compression ratio (typically 14:1 to 22:1).

Therefore, the compression ratio of a diesel cycle is significantly higher than that of an Otto cycle.

Quick Tip

Remember the ignition method: **Otto Cycle (Petrol):** Spark Ignition → Lower Compression Ratio (to prevent knock). **Diesel Cycle:** Compression Ignition → Higher Compression Ratio (to achieve ignition temperature).

---

36. Kelvin-plank's law deals with:
(A) Conversion of work into heat
(B) Conversion of heat into work
(C) Conservation of work
(D) Conservation of heat

Correct Answer: (B) Conversion of heat into work

Solution:
The Kelvin-Planck statement is one of the formulations of the Second Law of Thermodynamics.

It states: "It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work."

This statement places a fundamental limitation on the efficiency of heat engines. It implies that a heat engine must exchange heat with at least two reservoirs (a high-temperature source and a low-temperature sink) to produce net work.

Essentially, it governs the principles and limitations of converting heat energy into useful work.

The conversion of work into heat (A) is easily accomplished (e.g., through friction) and is not restricted by the second law.

Quick Tip

Think of the two main statements of the 2nd Law: **Kelvin-Planck:** Deals with Heat Engines and the impossibility of 100**Clausius:** Deals with Refrigerators/Heat Pumps and the impossibility of heat flowing from cold to hot without work input.

---

37. Which one of the following is an open pair?
(A) Ball and socket joint

(B) Journal bearing
(C) Lead screw and nut
(D) Cam and follower

Correct Answer: (D) Cam and follower

Solution:
Kinematic pairs are classified based on how their elements are held in contact.

Closed Pair (or Self-Closed Pair): The elements of the pair are held together mechanically due to their geometry. They cannot be separated without damaging the pair. Examples include Ball and socket joint, Journal bearing, and Lead screw and nut.

Open Pair (or Force-Closed Pair): The elements of the pair are not held together mechanically but are kept in contact by the action of an external force, such as gravity or a spring.

A cam and follower is a classic example of an open pair. The follower is typically held in contact with the cam's surface by a spring or its own weight. If this external force is removed, the contact between the cam and follower is lost.

Quick Tip

To identify an open pair, ask yourself: "Are the parts held together by their shape alone, or is a spring or gravity needed to keep them in contact?" If a spring or gravity is required, it's an open pair.

---

38. Shaft is subjected to which of the following stresses?
(A) Bending
(B) Torsional
(C) Both Bending and Torsional
(D) Tensile

Correct Answer: (C) Both Bending and Torsional

Solution:
A shaft is a rotating machine element used to transmit power from one place to another.

The transmission of power involves transmitting torque. Torque (T) on a shaft induces torsional shear stresses (τ).

In most applications, shafts are supported by bearings and carry components like gears, pulleys, or flywheels. The weight of these components and the forces acting on them (e.g., belt tension, gear tooth forces) create bending moments (M) in the shaft.

Bending moments induce bending stresses (σ_b), which are tensile on one side of the shaft and compressive on the other.

Therefore, a typical shaft in operation is subjected to a combination of both torsional stresses and bending stresses simultaneously. This combined loading is critical for shaft design.

Quick Tip

When you see the word "shaft" in a mechanics context, immediately think of combined loading. Power transmission implies torque (torsion), and the physical components mounted on the shaft imply forces (bending). The design must account for both.

---

39. Humidification increases:
(A) Dry bulb temp
(B) Moisture content of air
(C) Air velocity
(D) Pressure

Correct Answer: (B) Moisture content of air

Solution:
Humidification is the process of adding water vapor (moisture) to the air.

The amount of water vapor present in the air is quantified by properties like specific humidity (mass of water vapor per unit mass of dry air) or humidity ratio. Both of these are measures of the moisture content.

By its very definition, the process of humidification directly increases the moisture content of the air.

Other properties of the air also change. For example, in an adiabatic humidification process (like water spray), the dry bulb temperature decreases while the wet bulb temperature remains constant. However, the fundamental purpose and direct result of humidification is the increase in moisture content.

Quick Tip

On a psychrometric chart, the humidification process is represented by a vertical move upwards (increasing specific humidity). If it's simple humidification (e.g., steam injection), the line goes up and slightly to the right. If it's evaporative cooling, the line goes up and to the left along a constant wet-bulb temperature line.

---

40. The elastic strain energy stored in a rectangular cantilever beam of length L, subjected to a B.M., M applied at the end of it is:

(A) M^2L / 2 EI
(B) ML^2 / 2AE
(C) ML^3 / 3EI
(D) ML^2 / 16 EI

Correct Answer: (A) M^2L / 2 EI

Solution:

The elastic strain energy (U) stored in a beam due to bending is given by the general formula:
$U = \int_0^L \frac{M(x)^2}{2EI} dx$

Where $M(x)$ is the bending moment as a function of the distance x along the beam, E is the modulus of elasticity, and I is the moment of inertia.

For a cantilever beam with a pure bending moment M applied at its free end, the bending moment is constant at every cross-section along the beam's length L.
So, $M(x) = M$ (a constant).

Now we can evaluate the integral:
$U = \int_0^L \frac{M^2}{2EI} dx$

Since M, E, and I are constants, we can take them out of the integral:
$U = \frac{M^2}{2EI} \int_0^L 1 \cdot dx$

$U = \frac{M^2}{2EI} [x]_0^L$

$U = \frac{M^2}{2EI} (L - 0) = \frac{M^2 L}{2EI}$

Quick Tip

Remember the general formula for bending strain energy, $U = \int (M^2/2EI) dx$. For simple cases like constant moment or linearly varying moment, this integral becomes easy to solve. For a constant moment, it's simply $(M^2L)/(2EI)$.

41. A process in which no heat is transferred is called:
(A) Isobaric
(B) Adiabatic
(C) Isothermal
(D) Isochoric

Correct Answer: (B) Adiabatic

Solution:
In thermodynamics, processes are named based on the property that remains constant.

An adiabatic process is defined as a thermodynamic process in which there is no heat transfer into or out of the system.

The heat transfer, Q, is equal to zero ($Q = 0$).

The other options are defined as:
- Isobaric: Constant pressure process ($P =$ constant).
- Isothermal: Constant temperature process ($T =$ constant).
- Isochoric: Constant volume process ($V =$ constant).

Therefore, a process with no heat transfer is called adiabatic.

Quick Tip

Remember the thermodynamic prefixes: 'iso' means equal or constant. **Isobaric** = constant pressure. **Isothermal** = constant temperature. **Isochoric** = constant volume. **Adiabatic** comes from Greek 'adiabatos', meaning 'impassable', referring to the impassable heat boundary.

---

42. The main component in soldering is:
(A) Copper
(B) Tin-lead alloy
(C) Aluminium
(D) Nickel

Correct Answer: (B) Tin-lead alloy

Solution:
Soldering is a joining process that uses a filler metal (solder) with a low melting point to join

two or more metal items.

The most common and traditional type of solder is a metallic alloy.

Historically and most commonly, this alloy is composed of tin (Sn) and lead (Pb).

A common eutectic composition is 63
While modern regulations have led to the use of lead-free solders (e.g., tin-copper or tin-silver alloys), the tin-lead alloy remains the classic and defining component of traditional solder.

Quick Tip

Soldering is a low-temperature joining process. The primary material is solder, which is traditionally a tin-lead alloy. Distinguish this from brazing (higher temperature, uses alloys like brass) and welding (melts the base metals).

---

43. A refrigerator unit weighing 300 N is to be supported by three springs of stiffness of 10.26 kN/mm each. If the unit operates at 580 r.p.m., what should be the value of the spring constant k if only 10 **of the shaking force of the unit is to be transmitted to the supporting structure?**
(A) 2.4 N/mm
(B) 3.0 N/mm
(C) 3.4 N/mm
(D) 4 N/mm

Correct Answer: (C) 3.4 N/mm

Solution:
First, calculate the mass (m) and the forcing frequency (ω).
Weight W = 300 N, so mass $m = W/g = 300/9.81 \approx 30.58$ kg.
Operating speed N = 580 rpm.
Forcing frequency $\omega = 580 \times \frac{2\pi}{60} \approx 60.74$ rad/s.

The problem states that 10TR = 0.10.

The formula for transmissibility (assuming negligible damping) is $TR = \frac{1}{|\frac{\omega^2}{\omega_n^2} - 1|}$.
$0.1 = \frac{1}{|\left(\frac{\omega}{\omega_n}\right)^2 - 1|}$
$|\left(\frac{\omega}{\omega_n}\right)^2 - 1| = 10$
Since we want isolation, $\omega > \omega_n$, so $(\frac{\omega}{\omega_n})^2 > 1$.
$(\frac{\omega}{\omega_n})^2 - 1 = 10 \implies (\frac{\omega}{\omega_n})^2 = 11$.

Now, find the required natural frequency (ω_n).
$\omega_n^2 = \frac{\omega^2}{11} = \frac{(60.74)^2}{11} \approx 335.2\ (\text{rad/s})^2$.

The natural frequency is related to total stiffness (k_{total}) and mass by $\omega_n^2 = \frac{k_{total}}{m}$.
$k_{total} = m \cdot \omega_n^2 = 30.58 \times 335.2 \approx 10252$ N/m.

The unit is supported by three springs, so the stiffness of one spring (k) is:
$k = \frac{k_{total}}{3} = \frac{10252}{3} \approx 3417$ N/m.

Convert the stiffness to N/mm:
$k = 3417\ \text{N/m} \times \frac{1\ \text{m}}{1000\ \text{mm}} = 3.417$ N/mm.
This is approximately 3.4 N/mm.

Quick Tip

For vibration isolation, the goal is to make the natural frequency (ω_n) of the system much lower than the forcing frequency (ω). This requires a 'soft' suspension (low stiffness, k) and/or a high mass (m). Isolation is effective when the frequency ratio $\omega/\omega_n > \sqrt{2}$.

---

44. The required diameter of the blank for the deep drawing of a cup of diameter 'd' and height 'h' is given by:
(A) $\sqrt{d^2 - 2dh}$
(B) $\sqrt{d^2 + 2dh}$
(C) $\sqrt{d^2 - 4dh}$
(D) $\sqrt{d^2 + 4dh}$

Correct Answer: (D) $\sqrt{d^2 + 4dh}$

Solution:
The blank diameter (D) for deep drawing is estimated by assuming the surface area of the initial flat blank is equal to the surface area of the final drawn cup. This assumes no material loss or significant thinning.

Surface area of the circular blank = $A_{blank} = \frac{\pi}{4}D^2$.

Surface area of the drawn cup = (Area of the circular base) + (Area of the cylindrical wall).
$A_{cup} = \left(\frac{\pi}{4}d^2\right) + (\pi dh)$.

Equating the two areas:
$A_{blank} = A_{cup}$
$\frac{\pi}{4}D^2 = \frac{\pi}{4}d^2 + \pi dh$

Divide the entire equation by $\frac{\pi}{4}$:
$D^2 = d^2 + 4dh$

Take the square root of both sides to find the blank diameter D:
$D = \sqrt{d^2 + 4dh}$

Quick Tip

This formula for blank diameter is a direct application of the conservation of surface area. Remember to equate the area of the initial blank ($\frac{\pi}{4}D^2$) with the area of the final shape (base + walls).

---

45. If the ratio of the diameter of rivet hole to the pitch of rivets is 0.30, then the tearing efficiency of the joint is:
(A) 70(B) 60(C) 50(D) 30

Correct Answer: (A) 70

Solution:
The tearing efficiency ($\eta_{tearing}$) of a riveted joint is defined as the ratio of the tearing strength of the perforated plate to the strength of the solid plate.

Let 'p' be the pitch of the rivets and 'd' be the diameter of the rivet hole.
The tearing strength of the plate per pitch length is the force required to tear the plate between the rivet holes. It is calculated based on the net area resisting tearing.
Tearing Strength = $(p - d) \times t \times \sigma_t$, where t is the plate thickness and σ_t is the allowable tensile stress.

The strength of the solid plate per pitch length is based on the gross area.
Strength of Solid Plate = $p \times t \times \sigma_t$.

The tearing efficiency is the ratio of these two strengths:
$\eta_{tearing} = \frac{(p-d)\times t\times\sigma_t}{p\times t\times\sigma_t} = \frac{p-d}{p} = 1 - \frac{d}{p}$.

The problem gives the ratio $\frac{d}{p} = 0.30$.
$\eta_{tearing} = 1 - 0.30 = 0.70$.

To express this as a percentage, multiply by 100:
Efficiency = $0.70 \times 100\% = 70\%$.

Quick Tip

The efficiency of a joint is always (Strength of Joint) / (Strength of Solid Plate). For tearing efficiency, the strength is reduced by the material removed for the rivet hole, so the formula is simply $\eta_t = (p - d)/p = 1 - (d/p)$.

---

46. In thin cylindrical pressure vessels, hoop stress is:
(A) Equal to axial stress
(B) Half of axial stress
(C) Twice the axial stress
(D) One-fourth axial stress

Correct Answer: (C) Twice the axial stress

Solution:
For a thin cylindrical pressure vessel subjected to an internal pressure 'P', with diameter 'd' and wall thickness 't', two principal stresses are developed.

1. **Hoop Stress (σ_h)** or Circumferential Stress: This stress acts along the circumference of the cylinder and resists the bursting of the cylinder along its length. The formula is: $\sigma_h = \frac{Pd}{2t}$.

2. **Axial Stress (σ_a)** or Longitudinal Stress: This stress acts along the length (axis) of the cylinder and resists the bursting of the cylinder across its diameter. The formula is: $\sigma_a = \frac{Pd}{4t}$.

To compare the two stresses, we can take their ratio:
$\frac{\sigma_h}{\sigma_a} = \frac{Pd/2t}{Pd/4t} = \frac{1/2}{1/4} = 2$.

Therefore, $\sigma_h = 2\sigma_a$. The hoop stress is twice the axial stress.

Quick Tip

Remember the formulas: Hoop Stress $\sigma_h = Pd/2t$ and Axial Stress $\sigma_a = Pd/4t$. Since the hoop stress is twice the axial stress, failure in a thin cylinder (like an overinflated sausage) will always occur by splitting along its length.

---

47. Cores are used to:
(A) Make desired recess in castings
(B) Strengthen moulding sand
(C) Support loose pieces
(D) Remove pattern easily

Correct Answer: (A) Make desired recess in castings

Solution:
In metal casting, a mold is used to create the external shape of the cast part.

A core is a separate, pre-formed insert made of sand or another refractory material that is placed inside the mold cavity before the molten metal is poured.

The function of the core is to occupy space where molten metal is not supposed to flow.

After the casting solidifies, the mold is removed, and the core is broken up and removed from the casting.

This leaves behind a hollow section, an internal cavity, or a recess in the finished casting.

Therefore, cores are used to create desired internal features or recesses in castings.

Quick Tip

Think of the mold as creating the outside of the object, and the core as creating the inside (the hollow parts). For example, to cast a hollow pipe, you need a cylindrical mold for the outer shape and a cylindrical core for the inner hole.

---

48. Austempering is the heat treatment process used to obtain:
(A) Low hardness
(B) High toughness
(C) High hardness
(D) High ductility

Correct Answer: (C) High hardness

Solution:
Austempering is an isothermal heat treatment process applied to steels.

The process involves: 1. Heating the steel to the austenitizing temperature. 2. Quenching it rapidly in a medium (like a salt bath) held at a constant temperature above the martensite start temperature (Ms), typically in the range of 250-550°C. 3. Holding at this temperature until the austenite transforms completely into bainite.

Bainite is a microstructure that consists of fine carbide particles in a ferrite matrix.

The resulting properties of a bainitic structure are a good combination of strength, high hardness (though typically less than fully hardened martensite), and excellent toughness and ductility.

Compared to a simple quench-and-temper process to achieve the same hardness, austempering often results in superior toughness and reduced distortion.

Given the options, both "High toughness" and "High hardness" are characteristics of the product. However, bainite is classified as a hard microstructure, significantly harder than annealed or normalized structures. Thus, "High hardness" is a correct description of the outcome.

Quick Tip

Heat Treatment Summary: **Annealing:** Softens the material (low hardness). **Quenching:** Produces Martensite (very high hardness, low toughness). **Tempering:** Reduces hardness and increases toughness of Martensite. **Austempering:** Produces Bainite (high hardness and high toughness).

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49. Natural frequency of undamped SDOF system is:
(A) $\sqrt{(m/k)}$
(B) $\sqrt{(k/m)}$
(C) k/m
(D) m/k

Correct Answer: (B) $\sqrt{(k/m)}$

Solution:
For an undamped Single Degree of Freedom (SDOF) spring-mass system, the equation of motion is derived from Newton's second law ($F = ma$).

The only force acting on the mass 'm' is the spring force, $F_s = -kx$, where 'k' is the stiffness and 'x' is the displacement.

So, $m\ddot{x} = -kx$.
Rearranging this gives the standard form of the equation for simple harmonic motion:
$m\ddot{x} + kx = 0$
or
$\ddot{x} + \frac{k}{m}x = 0$

This is in the form $\ddot{x} + \omega_n^2 x = 0$, where ω_n is the natural circular frequency.

By comparing the two equations, we can see that:
$\omega_n^2 = \frac{k}{m}$

Therefore, the natural frequency is:
$\omega_n = \sqrt{\frac{k}{m}}$

Quick Tip

The natural frequency $\omega_n = \sqrt{k/m}$ has units of radians per second. To get the frequency in Hertz (cycles per second), use $f_n = \frac{1}{2\pi}\sqrt{k/m}$. Remember that a stiffer system (high k) or a lighter system (low m) will vibrate faster.

---

50. Which of the following casting process used an expendable pattern?
(A) CO casting
(B) Die casting
(C) Centrifugal casting
(D) Investment casting

Correct Answer: (D) Investment casting

Solution:
Casting processes can be classified based on the type of pattern used.

Expendable Pattern: The pattern is used only once and is destroyed or consumed as part of the process.
Permanent Pattern: The pattern is made of a durable material (like wood or metal) and is reused multiple times.

Let's analyze the options:
- CO casting, die casting, and centrifugal casting all use permanent patterns or molds. The mold/pattern is not destroyed and is used for multiple production cycles.

- Investment casting uses a pattern made of wax or a similar material. This wax pattern is melted and drained from the mold before the metal is poured. The pattern is thus "lost" or expended in the process. This is why it's also called the "lost-wax process."

Therefore, investment casting is an expendable pattern process.

Quick Tip

The two main expendable pattern processes are Investment Casting (lost-wax) and Lost-Foam Casting. In both, the pattern is made of a material that can be removed from the mold by melting or vaporization.

---

51. In drawing operation, the metal flows due to:
(A) Ductility
(B) Work hardening
(C) Plasticity
(D) Shearing

Correct Answer: (C) Plasticity

Solution:
Drawing is a metal forming process where a material is pulled through a die to reduce its cross-section.

This process relies on the material's ability to undergo large permanent deformation without fracturing when a stress is applied.

This property is known as plasticity.

Plasticity is the fundamental material property that allows for all forming operations like drawing, rolling, and forging.

Ductility is a specific measure of plasticity (the ability to be drawn into a wire), but plasticity is the broader, more fundamental property. Work hardening is a consequence of plastic deformation, not the cause of metal flow.

Quick Tip

Plasticity is the property that enables metal forming operations. Think of it as the ability of a material to be molded into a new shape permanently. Ductility and malleability are specific types of plasticity.

---

52. The rake angle is a property of:
(A) Tool wear
(B) Tool geometry
(C) Workpiece shape

(D) Cutting fluid

Correct Answer: (B) Tool geometry

Solution:
In metal cutting, the shape and angles of the cutting tool are critically important. These features are collectively known as the tool geometry.

The tool geometry is described by a series of angles, including the rake angle, clearance (or relief) angle, and cutting edge angles.

The rake angle specifically is the angle of the tool's rake face (the surface along which the chip flows) relative to a reference plane.

It is a fundamental part of the tool's design and is therefore a property of the tool geometry.

Tool wear is a result of using the tool, and it changes the tool geometry over time, but the rake angle is an initial design parameter.

> **Quick Tip**
>
> Remember the key elements of a cutting tool's signature or geometry: rake angle, clearance angle, and cutting edge angles. The rake angle is crucial as it controls chip formation and cutting forces.

---

53. A Mohr's circle reduces to a point when the body is subjected to:
(A) Pure shear
(B) Uniaxial stress only
(C) Equal and opposite axial stresses on two mutually perpendicular planes, the planes being free of shear
(D) Equal axial stresses on two mutually perpendicular planes, the planes being free of shear.

Correct Answer: (D) Equal axial stresses on two mutually perpendicular planes, the planes being free of shear.

Solution:
The radius (R) of Mohr's circle for a 2D state of stress is given by the formula:
$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

For the circle to reduce to a single point, its radius must be zero ($R = 0$).

This requires both terms inside the square root to be zero.
1. $\tau_{xy}^2 = 0 \implies \tau_{xy} = 0$. This means the planes must be free of shear stress.
2. $\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 = 0 \implies \sigma_x - \sigma_y = 0 \implies \sigma_x = \sigma_y$. This means the normal stresses on the two perpendicular planes must be equal.

This condition, where $\sigma_x = \sigma_y$ and $\tau_{xy} = 0$, is known as a hydrostatic or isotropic state of stress. Option (D) correctly describes this state.

Quick Tip

A point on Mohr's circle represents a hydrostatic state of stress. In this state, the normal stress is the same in all directions, and the shear stress is zero on all planes. The radius of the circle is zero.

---

54. In a throttling process, which one of the parameters remains constant?
(A) Temperature
(B) Pressure
(C) Enthalpy
(D) Entropy

Correct Answer: (C) Enthalpy

Solution:
A throttling process is a thermodynamic process in which a fluid is forced to flow through a restriction (like a valve, porous plug, or capillary tube) under adiabatic conditions ($Q = 0$) and with no work done ($W = 0$).

Applying the Steady Flow Energy Equation (SFEE) to a throttling device:
$h_1 + \frac{V_1^2}{2} + gz_1 + Q = h_2 + \frac{V_2^2}{2} + gz_2 + W$

For throttling, we assume:
- No heat transfer: $Q = 0$.
- No work done: $W = 0$.
- Negligible change in potential energy: $gz_1 \approx gz_2$.
- Negligible change in kinetic energy: $\frac{V_1^2}{2} \approx \frac{V_2^2}{2}$.

The SFEE simplifies to:
$h_1 = h_2$

This means the enthalpy of the fluid remains constant during the throttling process. Such a process is also called isenthalpic.

Quick Tip

Throttling = Isenthalpic process (h = constant). This is a key principle for refrigeration and air conditioning cycles, where an expansion valve is used to throttle the refrigerant.

---

55. Resonance occurs when:
(A) Damping is high
(B) Mass equals stiffness
(C) Forcing frequency equals natural frequency
(D) Displacement is zero

Correct Answer: (C) Forcing frequency equals natural frequency

Solution:
Resonance is a phenomenon that occurs in oscillating systems when a periodic driving force is applied at a frequency that matches the system's natural frequency of vibration.

The natural frequency (ω_n) is the frequency at which a system will oscillate if disturbed from its equilibrium position and then left to vibrate freely.

When the forcing frequency (ω) of an external periodic force approaches the natural frequency (ω_n), the amplitude of the system's oscillations grows dramatically.

The condition for resonance is:
$\omega = \omega_n$

High damping (A) reduces the amplitude at resonance but does not prevent it. The condition in (B) is dimensionally incorrect. Displacement (D) is maximum at resonance, not zero.

Quick Tip

Resonance is the matching of forcing frequency to natural frequency, leading to large amplitude vibrations. Famous examples include a singer shattering a glass, the Tacoma Narrows Bridge collapse, and pushing a child on a swing in rhythm.

---

56. Brazing differs from soldering primarily in the following
(A) Type of base metal used
(B) Temperature of the filler metal
(C) Use of electricity
(D) Type of shielding gas used

Correct Answer: (B) Temperature of the filler metal

Solution:
Brazing and soldering are both metal-joining processes where a filler metal is melted and flows into the joint, bonding the workpieces together without melting them.

The primary and defining difference between the two processes is the melting point of the filler metal used.

By convention:
- In **Soldering**, the filler metal (solder) has a melting point **below** 450°C (840°F).
- In **Brazing**, the filler metal (brazing alloy) has a melting point **above** 450°C (840°F), but still below the melting point of the base metals being joined.

This temperature difference is the fundamental distinction.

Quick Tip

Remember the 450°C (840°F) dividing line: - **Below 450°C** = Soldering - **Above 450°C** = Brazing This higher temperature generally results in stronger joints for brazing compared to soldering.

---

57. The addition of coal dust to the green moulding sand is to improve:
(A) Permeability
(B) Surface finish
(C) Mouldability
(D) Green strength

Correct Answer: (B) Surface finish

Solution:
Coal dust, also known as sea coal, is a common carbonaceous additive in green sand molding.

When the hot molten metal is poured into the mold, the heat from the metal causes the coal dust to volatilize, releasing hydrocarbon gases.

This has two main benefits:
1. It creates a gaseous cushion at the interface between the molten metal and the sand mold. This thin layer of gas prevents the metal from penetrating the pores of the sand and fusing with the sand grains.
2. The gases create a reducing atmosphere, which prevents oxidation of the metal surface that

is in contact with the mold.

Both of these effects result in a casting with a smoother, cleaner surface finish and make it easier to remove the casting from the mold.

Quick Tip

In sand casting, different additives serve specific purposes: - **Clay (e.g., Bentonite):** Acts as a binder for strength. - **Water:** Activates the clay binder. - **Coal Dust/Sea Coal:** Improves surface finish. - **Wood Flour/Cereals:** Improves collapsibility and reduces expansion defects.

---

58. Seam welding used for metal sheets having thickness in the range:
(A) 0.025 to 3 mm
(B) 3 to 6 mm
(C) 6 to 10 mm
(D) More than 10 m

Correct Answer: (A) 0.025 to 3 mm

Solution:
Seam welding is a type of resistance welding process that produces a continuous, leak-proof weld. It can be thought of as a series of overlapping spot welds.

The process uses two rotating wheel-like electrodes to apply pressure and convey the welding current to the workpieces.

This process is particularly well-suited for joining thin sheets of metal, as it can be done quickly and produces a continuous joint.

It is commonly used to fabricate items like fuel tanks, drums, and radiators.

The typical thickness range for materials that can be effectively joined by seam welding is from very thin foils (around 0.025 mm) up to about 3 mm. Thicker materials require excessively high currents and pressures, making other welding processes more suitable.

Quick Tip

Resistance welding processes like spot welding and seam welding are most effective on thin metal sheets. The practical upper limit for common applications is around 3 mm.

59. Which of the following is a Taylor's tool life equation, where V-cutting speed (m/min), T-tool life (min), n-exponent and C-constant?
(A) TV^n = C
(B) VT^n = C
(C) VC^n = T
(D) CV^n = T

Correct Answer: (B) VT^n = C

Solution:
Taylor's tool life equation is an empirical model that establishes a relationship between the cutting speed (V) and the resulting tool life (T).

The standard form of the equation is:
$VT^n = C$

Where:
- V is the cutting speed (e.g., in m/min).
- T is the tool life (e.g., in min).
- n is the Taylor tool life exponent, a constant that depends primarily on the tool material.
- C is the Taylor constant, which is the cutting speed for a tool life of one minute.

This equation shows that as the cutting speed (V) increases, the tool life (T) decreases exponentially.

Quick Tip

Memorize the standard form: $VT^n = C$. A simple way to remember is "Velocity times Time to the power n is Constant". This relationship is fundamental to machining economics.

---

60. CAD/CAM is hardware oriented, but gives it life.
(A) Numerical control
(B) Documentation
(C) Software
(D) Communications

Correct Answer: (C) Software

Solution:
The question presents an analogy to describe the components of a CAD/CAM system.

A CAD/CAM system is composed of two main elements:
1. **Hardware:** This includes the physical components like the computer, monitor, mouse, plotter, and the CNC machine itself. The question refers to this as being "hardware oriented".
2. **Software:** This includes the programs and instructions that run on the hardware. The CAD software is used for design and drafting, while the CAM software generates the toolpaths and code (like G-code) to control the CNC machine.

The phrase "gives it life" poetically describes the function of the software. Without the software, the hardware is just an inert collection of electronic and mechanical parts. The software provides the intelligence and instructions that make the hardware perform its intended tasks.

Quick Tip

Think of any computer-based system (like a smartphone or a gaming console). The physical device is the hardware, but it's the operating system and the apps (the software) that make it useful and "bring it to life". The same applies to CAD/CAM systems.

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61. EDM (Electric Discharge Machining) is suitable for:
(A) Plastic parts
(B) Hard conductive materials
(C) Wooden molds
(D) Composites

Correct Answer: (B) Hard conductive materials

Solution:
Electric Discharge Machining (EDM) is a non-traditional machining process.

Its material removal mechanism is based on thermoelectric energy. It uses a series of rapidly recurring electrical discharges (sparks) between an electrode (the tool) and the workpiece.

These sparks melt and vaporize microscopic amounts of material from the workpiece.

A fundamental requirement for this process to work is that both the tool and the workpiece must be electrically conductive.

EDM's main advantage is its ability to machine materials regardless of their hardness. It can easily machine hardened tool steels, carbides, and exotic alloys that are very difficult to machine with traditional methods.

Therefore, EDM is most suitable for hard, electrically conductive materials. Materials like plastics, wood, and most composites are non-conductive and cannot be machined by EDM.

Quick Tip

For EDM, remember two key requirements: the workpiece must be electrically conductive, and the process is independent of material hardness. This makes it ideal for creating intricate shapes in hardened tool steels and superalloys.

---

62. The continuity equation $\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0$ is valid only for:
(A) Ideal fluid flow
(B) Incompressible fluid
(C) Steady flow and incompressible fluids
(D) Steady flow and compressible fluids

Correct Answer: (C) Steady flow and incompressible fluids

Solution:
The general form of the continuity equation, based on the principle of conservation of mass, is:
$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0$

This equation is valid for any fluid flow (steady or unsteady, compressible or incompressible).

Now let's apply the conditions given in the options to simplify this general equation.

1. For **steady flow**, the properties at any point do not change with time, so $\frac{\partial \rho}{\partial t} = 0$. The equation becomes:
$\frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0$

2. For an **incompressible fluid**, the density ρ is constant. This means we can take ρ out of the derivatives. The equation becomes:
$\rho \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right) = 0$
Dividing by ρ gives the final form:
$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$ (or using d for partial derivatives in this context)

Therefore, the given equation is valid when the flow is both steady and the fluid is incompressible.

Quick Tip

The continuity equation in its simplest form, $\nabla \cdot \vec{V} = 0$, represents the conservation of mass for a steady, incompressible flow. The general form includes terms for changing density and time dependency.

---

63. In a planar truss, the number of members (m), joints (j), and reactions (r) are related by:
(A) m + r = 2j
(B) m + j = 2r
(C) m + r = j
(D) m + j = r

Correct Answer: (A) m + r = 2j

Solution:
This question relates to the condition for a planar truss to be statically determinate.

A planar truss is a structure made of straight members connected at joints, forming a rigid framework.

For a truss to be in static equilibrium, the number of unknown forces must be equal to the number of available independent equilibrium equations.

The unknown forces are the internal forces in the members (m) and the external support reactions (r). Total unknowns = m + r.

At each joint in a planar truss, we can write two equilibrium equations: $\Sigma F_x = 0$ and $\Sigma F_y = 0$. For a truss with 'j' joints, the total number of available equilibrium equations is 2j.

For the truss to be statically determinate, the number of unknowns must equal the number of equations:
Total Unknowns = Total Equations
$m + r = 2j$

This equation is the condition for a planar truss to be a perfect or statically determinate frame.

Quick Tip

For trusses, remember the determinacy conditions: **2D (Planar) Truss:** $m+r = 2j$ **3D (Space) Truss:** $m+r = 3j$ If $m+r > 2j$, it's indeterminate (redundant). If $m+r < 2j$, it's a mechanism (unstable).

64. Quick return mechanism is an inversion of:
(A) Four bar chain
(B) Single slider crank chain
(C) Double slider crank chain
(D) Crossed slider crank chain

Correct Answer: (B) Single slider crank chain

Solution:
A kinematic chain becomes a mechanism when one of its links is fixed. Different mechanisms, called inversions, can be obtained by fixing different links of the same kinematic chain.

A single slider crank chain has four links: a fixed link (frame), a crank, a connecting rod, and a slider.

Several important mechanisms are inversions of the single slider crank chain:
1. **First Inversion (Frame fixed):** The standard reciprocating engine or compressor.
2. **Second Inversion (Crank fixed):** Whitworth quick return mechanism, Rotary engine.
3. **Third Inversion (Connecting rod fixed):** Crank and slotted lever quick return mechanism, Oscillating cylinder engine.
4. **Fourth Inversion (Slider fixed):** Hand pump.

Mechanisms like the Whitworth and the Crank and slotted lever are types of quick return mechanisms, which are used in machines like shapers and slotters. Since these are obtained by fixing different links of the single slider crank chain, the quick return mechanism is an inversion of the single slider crank chain.

Quick Tip

Associate the key mechanisms with their parent kinematic chain: - **Four bar chain:** Beam engine, Watt's indicator mechanism. - **Single slider crank chain:** Reciprocating engine, Whitworth quick return, Crank and slotted lever. - **Double slider crank chain:** Elliptical trammel, Scotch yoke, Oldham's coupling.

65. In wire drawing operation, the maximum reduction per pass for perfectly plastic material in ideal condition is:
(A) 30(B) 45(C) 63(D) 50

Correct Answer: (C) 63

Solution:
For an ideal wire drawing process (no friction, no redundant work) of a perfectly plastic material, the maximum possible reduction in cross-sectional area per pass can be derived from stress

analysis.

The drawing stress (σ_d) is given by:
$\sigma_d = \sigma_0 \ln\left(\frac{A_i}{A_f}\right)$
where σ_0 is the yield stress, A_i is the initial area, and A_f is the final area.

The drawing operation is only possible if the drawing stress is less than the yield stress of the drawn wire. In the limiting case, the drawing stress equals the yield stress.
$\sigma_d = \sigma_0$

Setting the two equations equal:
$\sigma_0 = \sigma_0 \ln\left(\frac{A_i}{A_f}\right)$
$1 = \ln\left(\frac{A_i}{A_f}\right)$

Exponentiating both sides (base e):
$e^1 = \frac{A_i}{A_f} \implies \frac{A_f}{A_i} = \frac{1}{e}$

The fractional reduction in area (R) is:
$R = \frac{A_i - A_f}{A_i} = 1 - \frac{A_f}{A_i} = 1 - \frac{1}{e}$

Using the value $e \approx 2.718$:
$R = 1 - \frac{1}{2.718} \approx 1 - 0.3678 = 0.6322$

Expressed as a percentage, the maximum reduction is approximately 63.2

Quick Tip

The theoretical maximum reduction in area for ideal drawing or extrusion is $(1 - 1/e)$, which is approximately 63.2

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66. In metal cutting operations, discontinuous chips are produced while machining:
(A) Brittle material
(B) Ductile material
(C) Hard material
(D) Soft material

Correct Answer: (A) Brittle material

Solution:
The type of chip produced during a machining operation depends on the material properties of the workpiece, cutting conditions, and tool geometry.

Discontinuous Chips: These are chips that are produced as small, separate segments. They form when the material being cut has low ductility. As the tool advances, the stress ahead of it builds up until the material fractures, creating a segment of the chip. This process repeats, forming a series of broken pieces.

This type of chip is characteristic of machining brittle materials, such as cast iron and brass.

Continuous Chips: These are long, ribbon-like chips formed when machining ductile materials like mild steel, aluminum, and copper. The material deforms plastically in a shear zone and flows smoothly up the rake face of the tool.

Therefore, discontinuous chips are produced when machining brittle materials.

Quick Tip

Remember the basic chip types and their associated materials: - **Discontinuous Chips** $\rightarrow$ Brittle materials (e.g., Cast Iron). - **Continuous Chips** $\rightarrow$ Ductile materials (e.g., Mild Steel, Aluminum). - **Continuous Chips with Built-Up Edge (BUE)** $\rightarrow$ Ductile materials at low speeds.

---

67. Least count of a micrometer screw gauge is usually:
(A) 0.1 mm
(B) 0.01 mm
(C) 0.001 mm
(D) 1 mm

Correct Answer: (B) 0.01 mm

Solution:
The least count of a measuring instrument is the smallest measurement that can be accurately made with it.

A standard metric micrometer screw gauge has two scales: the main scale (on the sleeve) and the circular scale (on the thimble).

The main scale is typically marked in millimeters, with the smallest division being 0.5 mm.
The pitch of the screw is the distance it moves forward in one complete rotation, which is typically 0.5 mm.
The circular scale on the thimble usually has 50 divisions.

The least count is calculated as:
Least Count = $\frac{\text{Pitch of the screw}}{\text{Total number of divisions on the circular scale}}$

Least Count = $\frac{0.5 \text{ mm}}{50} = 0.01$ mm.

Therefore, the usual least count of a micrometer screw gauge is 0.01 mm. A vernier caliper, for comparison, usually has a least count of 0.02 mm.

Quick Tip

Typical least counts to remember: - **Steel Rule:** 0.5 mm or 1 mm. - **Vernier Caliper:** 0.02 mm. - **Micrometer Screw Gauge:** 0.01 mm. The micrometer is more precise than the vernier caliper.

---

68. In an open system, $both\_\_\_and\_\_\_cancrosstheboundary$**?**
(A) Heat and mass
(B) Work and energy
(C) Mass and energy
(D) Pressure and volume

Correct Answer: (C) Mass and energy

Solution:
Thermodynamic systems are defined by what can cross their boundaries.

Isolated System: Neither mass nor energy can cross the boundary.

Closed System (Control Mass): Energy (in the form of heat and work) can cross the boundary, but mass cannot.

Open System (Control Volume): Both mass and energy can cross the boundary.

Energy can cross the boundary of an open system in three ways: as heat, as work, and as energy associated with the mass that is flowing across the boundary (internal, kinetic, potential energies).

Therefore, in an open system, both mass and energy are allowed to cross the system boundary.

Quick Tip

Use a simple analogy: - **Isolated System** = A sealed, perfectly insulated thermos flask. - **Closed System** = A sealed bottle of water (can be heated/cooled, but no water enters/leaves). - **Open System** = A boiling pot of water without a lid (steam/mass leaves, and heat is added).

69. Reheating in Brayton cycle:
(A) Decreases work output
(B) Reduces temperature
(C) Increases work output
(D) Reduces efficiency

Correct Answer: (C) Increases work output

Solution:
Reheating in a Brayton cycle involves multi-stage expansion with heat addition between the stages.

The process is as follows: 1. Gas expands in a high-pressure turbine to some intermediate pressure. 2. The gas is then passed through a combustion chamber or "reheater" where more fuel is burned to raise its temperature again. 3. The reheated gas then expands in a low-pressure turbine to the final exhaust pressure.

On a T-s diagram, the area enclosed by the cycle represents the net work output. Reheating adds a "lobe" to the right side of the diagram, increasing the total area.

The work output from a turbine is proportional to the temperature drop across it. By reheating, we expand the gas from a higher average temperature, which increases the total work produced by the turbines.

While reheating does increase the turbine work output, it also requires more heat input and generally leads to a decrease in the cycle's thermal efficiency.

Therefore, the primary purpose and direct result of reheating is to increase the work output.

Quick Tip

Remember the effects of modifications to the Brayton cycle: - **Reheating:** Increases work output, decreases efficiency. - **Intercooling:** Decreases compressor work, increases work output and efficiency. - **Regeneration:** Increases efficiency, no change in work output.

70. Strength of a material is its ability to resist:
(A) Deformation due to stress
(B) Fracture due to high load
(C) External forces applied with yielding or break down

(D) The flow

Correct Answer: (C) External forces applied with yielding or break down

Solution:
Strength is a fundamental mechanical property of a material.

It is a measure of the material's capacity to withstand an applied stress without failure.

"Failure" can mean either yielding (the onset of permanent, plastic deformation) or fracture (complete separation or breakdown).

The strength is typically quantified by values like yield strength (stress at which yielding begins) or ultimate tensile strength (the maximum stress the material can withstand before fracture).

Option (C) provides the most comprehensive definition, as it encompasses resistance to external forces without undergoing either yielding or breakdown (fracture).

Option (A), resistance to deformation, is related to stiffness (modulus of elasticity), not strength. Option (B) is too specific as it only considers fracture.

> Quick Tip
>
> Distinguish between key material properties: - **Strength:** Resistance to failure (yielding or fracture). - **Stiffness (Rigidity):** Resistance to elastic deformation (how much it stretches under load). - **Toughness:** Ability to absorb energy before fracturing (area under the stress-strain curve). - **Hardness:** Resistance to localized surface indentation.

---

71. As the distance from the leading edge increases, the thermal boundary layer thickness:
(A) Increases
(B) Remains constant
(C) Decreases
(D) Becomes zero

Correct Answer: (A) Increases

Solution:
When a fluid flows over a flat plate with a different temperature, a thermal boundary layer develops.

The thermal boundary layer is the region of the fluid where the temperature changes from the surface temperature (T_s) to the free stream temperature (T_∞).

At the leading edge of the plate (where the distance x=0), the boundary layer thickness is zero.

As the fluid flows along the plate, heat is transferred between the plate and the fluid. This thermal effect diffuses further and further into the fluid stream.

Consequently, the thickness of the thermal boundary layer grows with increasing distance 'x' from the leading edge.

For laminar flow, the thickness (δ_t) is proportional to $\sqrt{x}$. For turbulent flow, it is proportional to $x^{0.8}$. In both cases, the thickness increases with distance.

Quick Tip

Both the hydrodynamic (velocity) boundary layer and the thermal boundary layer grow in thickness as the fluid moves along a surface. They both start with zero thickness at the leading edge.

---

72. Provision of fins on a given heat transfer surface will be more, if there are:
(A) Fewer number of thick fins
(B) Fewer number of thin fins
(C) Large number of thin fins
(D) Large number of thick fins

Correct Answer: (C) Large number of thin fins

Solution:
The primary purpose of adding fins to a surface is to increase the total surface area available for heat transfer, thereby enhancing the rate of heat dissipation.

The rate of heat transfer (Q) is given by Newton's law of cooling: $Q = hA\Delta T$. To increase Q, we need to increase the area, A.

To maximize the surface area for a given volume or base area, it is more effective to have a large number of fins.

Furthermore, for a fin to be effective, heat must be conducted efficiently from its base to its tip. The effectiveness of a fin is generally higher for fins with a large perimeter-to-cross-sectional-area ratio (P/A). Thin fins have a larger P/A ratio compared to thick fins of the same length.

Combining these two factors, the most effective way to increase heat transfer is to use a large number of thin fins, as this configuration provides the maximum surface area and promotes better heat distribution along each fin.

Quick Tip

To maximize heat transfer with fins, you want to maximize the surface area. A large number of thin fins will always provide more surface area than a small number of thick fins occupying the same base area.

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73. The primary mechanism of material removal in electrochemical machining (ECM) is:

(A) Chemical corrosion
(B) Ionic dissolution
(C) Etching
(D) Spark erosion

Correct Answer: (B) Ionic dissolution

Solution:
Electrochemical Machining (ECM) is a non-traditional machining process that removes material by an anodic dissolution process.

The workpiece is made the anode (+) and the tool is made the cathode (-). They are separated by a small gap filled with a flowing electrolyte (e.g., a salt solution).

When a direct current is passed between the anode and cathode, a controlled electrochemical reaction occurs, which is essentially a rapid, localized version of corrosion.

This reaction removes metal atoms from the workpiece surface by converting them into metallic ions, which are then carried away by the flowing electrolyte.

This process of removing material atom by atom as ions is called ionic dissolution or anodic dissolution. It is based on Faraday's law of electrolysis.

Spark erosion (D) is the mechanism for Electric Discharge Machining (EDM).

Quick Tip

Remember the key mechanisms for non-traditional machining: - **ECM (ElectroChemical Machining):** Ionic/Anodic dissolution. - **EDM (Electric Discharge Machining):** Spark erosion (melting and vaporization). - **LBM (Laser Beam Machining):** Melting and vaporization.

---

74. In the S-N curve, "N" represents :
(A) Load cycles
(B) Number of cycles to failure
(C) Stress amplitude
(D) Time to failure

Correct Answer: (B) Number of cycles to failure

Solution:
An S-N curve, also known as a Wöhler curve, is a graph used to characterize the fatigue behavior of a material.

The curve is a plot of stress versus the number of cycles to failure.

- The vertical axis ('S') represents the stress level, typically the stress amplitude (S_a) or maximum stress (S_{max}) of a cyclic load.
- The horizontal axis ('N') represents the number of cycles the material can withstand at that stress level before failing due to fatigue.

Therefore, 'N' in the S-N curve stands for the Number of cycles to failure, often referred to as the fatigue life.

Quick Tip

The S-N curve is the fundamental graph for fatigue analysis. Remember S = Stress and N = Number of cycles to failure. For steels, the curve often becomes horizontal at a certain stress level, known as the endurance limit.

---

75. The value of poisson's ratio for any material cannot exceed:
(A) 0.2
(B) 1.0
(C) 1.414
(D) 0.5

Correct Answer: (D) 0.5

Solution:
Poisson's ratio (μ) is a measure of the transverse strain relative to the axial strain when a material is stressed.
$\mu = -\frac{\text{Lateral Strain}}{\text{Axial Strain}}$

From the theory of elasticity, the relationships between the elastic constants (E, G, K) impose limits on the possible values of Poisson's ratio.

The relationship $E = 3K(1-2\mu)$ is one such relation. Since both the modulus of elasticity (E) and the bulk modulus (K) must be positive for a stable, isotropic material, the term $(1-2\mu)$ must also be positive.
$1 - 2\mu > 0$
$1 > 2\mu$
$\mu < 0.5$

A material with $\mu = 0.5$ is a perfectly incompressible material (its volume does not change under elastic deformation), such as rubber. For metals, Poisson's ratio typically ranges from 0.25 to 0.35.

Therefore, the theoretical upper limit for Poisson's ratio for any material is 0.5.

Quick Tip

The theoretical range for Poisson's ratio is from -1.0 to 0.5. However, for most engineering materials, the practical range is from 0 to 0.5. A value of 0.5 signifies an incompressible material (like rubber).

---

76. Amount of external energy required to deform an elastic body is called:
(A) Elastic energy
(B) Plastic energy
(C) Strain energy
(D) Thermal energy

Correct Answer: (C) Strain energy

Solution:
When an external force is applied to an elastic body, the body deforms. The work done by this external force in causing the deformation is stored within the body as potential energy.

This internally stored energy is known as strain energy.

If the deformation is within the elastic limit, this stored energy is fully recoverable when the load is removed. This recoverable portion is also specifically called elastic strain energy.

The term "Strain Energy" is the general name for the energy stored in a body due to its deformation.

Option (A) is a more specific term for the recoverable part of this energy. Option (B) is incorrect as it relates to non-recoverable work. Option (C) is the most appropriate and general term.

Quick Tip

Strain energy is the energy stored in a material due to deformation. Think of it like the potential energy stored in a stretched spring. The area under the load-deflection curve represents the work done, which is equal to the strain energy stored.

---

77. Balancing of a rigid rotor can be achieved by appropriately balancing masses in:
(A) Single plane
(B) Two planes
(C) Three planes
(D) Four planes

Correct Answer: (B) Two planes

Solution:
A rigid rotor is an idealized rotating body where the deflections are negligible. Unbalance in a rotor can be of two types:

1. **Static Unbalance:** This occurs when the mass axis is displaced parallel to the axis of rotation. This can be corrected by adding a single mass in a single plane, opposite to the unbalance.

2. **Dynamic Unbalance:** This occurs when the mass axis is skewed and intersects the axis of rotation. This creates an unbalanced couple, which causes the rotor to wobble. Static balancing alone cannot correct this.

To correct for the most general case of unbalance, which is dynamic unbalance (and includes static unbalance as a special case), it is necessary to balance both the net unbalanced force and the net unbalanced couple.

It can be mathematically proven that any system of unbalanced forces and couples on a rigid rotor can be completely balanced by adding or removing correction masses in any two arbitrarily chosen transverse planes.

Quick Tip

Remember the rule for balancing: - **Static Balance** (for thin disks): Requires balancing in ONE plane. - **Dynamic Balance** (for long rotors): Requires balancing in TWO planes to eliminate both the net force and the net couple. Dynamic balance implies static balance, but not vice versa.

---

78. Forecasting in PPC helps in:
(A) Inventory disposal
(B) Machine maintenance
(C) Planning future production needs
(D) Waste disposal

Correct Answer: (C) Planning future production needs

Solution:
PPC stands for Production Planning and Control. It is a managerial function that aims to ensure that production proceeds efficiently and meets customer demand.

Forecasting is a critical input to the PPC process. It involves predicting the future demand for a company's products.

The forecast provides the basis for all subsequent planning activities.

Based on the demand forecast, the management can plan for:
- The quantity of products to be produced.
- The required raw materials and components (inventory planning).
- The necessary production capacity (machines, labor, shifts).
- The production schedule.

Therefore, the primary role of forecasting in PPC is to help in planning future production needs to meet the anticipated demand.

Quick Tip

Think of the PPC sequence: It starts with **Forecasting** (what will customers buy?), which leads to **Planning** (what materials, machines, and people do we need?), and then to **Control** (are we making things on time and to specification?).

79. Heat transfer takes place according to:
(A) Zeroth law of thermodynamics
(B) First law of thermodynamics
(C) Second law of thermodynamics
(D) Third law of thermodynamics

Correct Answer: (C) Second law of thermodynamics

Solution:
The laws of thermodynamics govern energy and its transformations.

The Zeroth Law defines temperature and thermal equilibrium. It states that if two systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other. This law implies that a temperature difference is necessary for heat transfer, but it doesn't specify the direction.

The First Law is the law of conservation of energy. It quantifies the amount of energy transferred as heat or work, but it does not specify the direction in which the heat transfer will occur.

The Second Law of Thermodynamics specifies the direction of natural processes. The Clausius statement of the second law says, "Heat can never pass from a colder to a warmer body without some other change, connected therewith, occurring at the same time."

This means that the natural direction of heat transfer is always from a body at a higher temperature to a body at a lower temperature. The second law thus governs the directionality of heat transfer.

Quick Tip

Remember what each law provides: - **Zeroth Law:** Defines temperature. - **First Law:** Quantifies energy (conservation). - **Second Law:** Specifies the direction of energy transfer (heat flows from hot to cold). - **Third Law:** Defines absolute zero.

80. The locus of elevations that water will rise in a series of pitot tubes is called:
(A) The hydraulic grade line
(B) The energy grade line
(C) The velocity head
(D) The pressure head

Correct Answer: (B) The energy grade line

Solution:
Let's define the key terms based on the Bernoulli equation:
Total Head $= z + \frac{P}{\rho g} + \frac{V^2}{2g}$

- **Piezometer Tube:** This is a simple tube open to the flow on its side. The water in a piezometer rises to a height corresponding to the static pressure head ($P/\rho g$) above the measurement point. The line connecting the water levels in a series of piezometers is the **Hydraulic Grade Line (HGL)**. The HGL represents the sum of the elevation head and the pressure head: $HGL = z + \frac{P}{\rho g}$.

- **Pitot Tube:** This tube has its opening facing directly into the flow. It measures the stagnation pressure, bringing the fluid to a stop at its tip. The water in a pitot tube rises to a height corresponding to the sum of the static pressure head and the velocity head ($\frac{P}{\rho g} + \frac{V^2}{2g}$). The line connecting the water levels in a series of pitot tubes is the **Energy Grade Line (EGL)**. The EGL represents the total head: $EGL = z + \frac{P}{\rho g} + \frac{V^2}{2g}$.

Therefore, the locus of elevations for a series of pitot tubes is the Energy Grade Line.

Quick Tip

Simple rule: - **Piezometer** measures pressure head $\rightarrow$ **Hydraulic Grade Line (HGL)**.
- **Pitot Tube** measures total head (pressure + velocity) $\rightarrow$ **Energy Grade Line (EGL)**.
The vertical distance between the EGL and the HGL is always equal to the velocity head, $V^2/2g$.

---

81. Which material is commonly used for pattern making?
(A) Cast iron
(B) Wood
(C) Bronze
(D) Lead

Correct Answer: (B) Wood

Solution:
A pattern is a replica of the object to be cast, used to prepare the cavity in the mold. The choice of pattern material depends on factors like the number of castings required, required dimensional accuracy, and cost.

Wood is one of the most common and widely used materials for making patterns.

Advantages of using wood include:
- It is inexpensive and easily available.

- It is lightweight and easy to work with (can be easily shaped).
- It has a good surface finish.

While metals like cast iron and aluminum are also used for patterns (called metal patterns), they are more expensive and are typically used for large-scale production where high durability and dimensional accuracy are required. For general-purpose, small-batch production, wood is the most common choice.

Quick Tip

For pattern materials, think about the production scale: - **Small-scale/Prototyping:** Wood is the most common due to its low cost and ease of shaping. - **Large-scale Production:** Metals (like Aluminum or Cast Iron) are used for their durability and long life. - **Special cases:** Wax (Investment Casting) or Polystyrene (Lost-Foam Casting) are used for expendable patterns.

---

82. The instantaneous centre of rotation of a rigid thin disc rolling on a plane rigid surface is located at:
(A) Centre of the disc
(B) An infinite distance on the plane surface
(C) The point of contact
(D) The point on the circumference situated vertically opposite to the contact point

Correct Answer: (C) The point of contact

Solution:
The instantaneous centre of rotation (ICR) is a point on a body undergoing planar motion that has zero velocity at a particular instant of time. The entire body can be considered to be in pure rotation about this point at that instant.

Consider a disc rolling without slipping on a plane surface.
The velocity of the center of the disc is V_c.
The velocity of any point on the disc is the vector sum of the translational velocity (V_c) and the rotational velocity ($r\omega$).

At the point of contact with the ground, the translational velocity is forward (V_c), and the velocity due to rotation is backward (tangential, equal to $R\omega$).

For rolling without slipping, the condition is $V_c = R\omega$.
So, the velocity at the point of contact is $V_{contact} = V_c - R\omega = V_c - V_c = 0$.

Since the point of contact has zero velocity, it is the instantaneous centre of rotation for the rolling disc.

Quick Tip

For any object rolling without slipping on a stationary surface, the instantaneous center of rotation (ICR) is always the point of contact between the object and the surface. The top point of the object will have a velocity of 2V, where V is the velocity of the center.

---

83. The gears employed for connecting two non-intersecting and non-parallel, i.e., non-coplanar shafts are:
(A) Bevel gears
(B) Spiral gears
(C) Helical gears
(D) Mitre gears

Correct Answer: (B) Spiral gears

Solution:
The type of gear used depends on the relative orientation of the shafts to be connected.

- **Parallel Shafts:** Spur gears or Helical gears.
- **Intersecting Shafts:** Bevel gears (including Mitre gears, which are a special case of bevel gears with a 1:1 ratio and 90° shaft angle).
- **Non-intersecting and Non-parallel (Skew or Non-coplanar) Shafts:** This is the case described in the question. The gears used for this configuration are Spiral gears or Worm gears.

Spiral gears are essentially helical gears used to connect skew shafts. Unlike helical gears on parallel shafts which have line contact, spiral gears on skew shafts have point contact.

Therefore, spiral gears are the correct choice for connecting non-intersecting, non-parallel shafts.

Quick Tip

Memorize the gear types by shaft orientation: - **Parallel Shafts:** Spur, Helical. - **Intersecting Shafts:** Bevel. - **Non-intersecting, Non-parallel (Skew):** Spiral, Worm.

---

84. Which of the machining process uses the principle of faraday's law for material removal?
(A) EDM
(B) LBM

(C) ECM
(D) EBM

Correct Answer: (C) ECM

Solution:
Faraday's laws of electrolysis describe the quantitative aspects of electrolysis. They state that the amount of chemical change (and thus mass of material removed or deposited) is directly proportional to the magnitude of the electric charge passed through the electrolyte.

Let's examine the processes:
- **EDM (Electric Discharge Machining):** Removes material by thermal energy from electric sparks. It does not follow Faraday's law.
- **LBM (Laser Beam Machining):** Uses high-energy light (thermal energy) to melt and vaporize material.
- **ECM (Electrochemical Machining):** Removes material by anodic dissolution, which is an electrolysis process. The rate of material removal in ECM is directly governed by Faraday's laws. The amount of material dissolved is proportional to the current and the time for which it flows.
- **EBM (Electron Beam Machining):** Uses a high-velocity beam of electrons (kinetic and thermal energy) to melt and vaporize material.

Therefore, Electrochemical Machining (ECM) is the process that uses the principle of Faraday's law.

Quick Tip

The "Chemical" in ElectroChemical Machining (ECM) is the key. ECM is essentially controlled, high-speed corrosion (electrolysis). Electrolysis is governed by Faraday's Laws.

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85. A master gauge is a an:
(A) New gauge
(B) International reference standard
(C) Standard gauge for checking accuracy of gauges used on shop floors
(D) Gauge used by experienced technicians

Correct Answer: (C) Standard gauge for checking accuracy of gauges used on shop floors

Solution:
In metrology, a hierarchy of standards and gauges is used to ensure accuracy and traceability.

- **Working Gauges:** These are the gauges used directly on the shop floor for routine inspection of parts during production. They are subject to wear and tear.

- **Inspection Gauges:** These are used by inspectors to check parts and also to verify the accuracy of the working gauges. They are kept in better condition than working gauges.

- **Master Gauges (or Reference Gauges):** These are high-precision gauges that are not used for direct measurement of parts. Their primary purpose is to calibrate or check the accuracy of the inspection gauges and working gauges. They are kept in a controlled environment and handled carefully to maintain their accuracy.

The master gauges themselves are calibrated against even higher standards (like national or international standards).

Therefore, a master gauge is a standard used to check the accuracy of gauges used on the shop floor.

Quick Tip

Think of the gauge hierarchy like a chain of command for accuracy: **Primary/International Standard → National Standard → Master Gauge → Inspection Gauge → Working Gauge → Workpiece**. Each level is used to check the accuracy of the level below it.

---

86. Gating system in casting controls:
(A) Cooling rate only
(B) Flow of molten metal
(C) Pouring time
(D) Mold expansion

Correct Answer: (B) Flow of molten metal

Solution:
The gating system in a casting mold is the network of channels through which the molten metal flows from the pouring basin to the mold cavity.

It typically consists of a pouring basin, sprue, runners, and gates.

The primary functions of the gating system are:
1. To introduce the molten metal into the mold cavity.
2. To control the rate at which the metal flows and the mold fills.
3. To promote smooth, non-turbulent flow to avoid defects like gas porosity and sand erosion.

4. To help trap impurities and slag, preventing them from entering the mold cavity.

Therefore, the most fundamental purpose of the gating system is to control the flow of the molten metal. While it influences the pouring time and can indirectly affect the cooling rate, its direct and primary function is flow control.

Quick Tip

The gating system is like the plumbing for a casting mold. Its job is to guide the molten metal smoothly and cleanly from the "faucet" (pouring cup) to the "bathtub" (mold cavity) without making a mess (i.e., causing defects).

---

87. For the two shafts connected in parallel, find which statement is true?
(A) Torque in each shaft is the same
(B) Shear stress in each shaft is the same
(C) Angle of twist of each shaft is the same
(D) Torsional stiffness of each shaft is the same.

Correct Answer: (C) Angle of twist of each shaft is the same

Solution:
When two shafts are connected in parallel, they are fixed together at both ends so that they twist together as a single unit.

This is analogous to two springs connected in parallel.

The key characteristics of a parallel shaft connection are:
1. **Angle of Twist:** Since they are fixed together and twist as one, the angle of twist (θ) must be the same for both shafts. $\theta_1 = \theta_2$.

2. **Total Torque:** The total torque applied to the composite system (T_{total}) is shared between the two shafts. The sum of the torques in the individual shafts equals the total torque. $T_{total} = T_1 + T_2$.

The torque is not necessarily the same in each shaft; it is distributed based on their respective torsional stiffnesses ($T = k_t\theta$). The shaft with higher stiffness will carry more torque.
Since torque and stiffness can be different, the shear stress will also generally be different.

Therefore, the defining and always true statement for shafts in parallel is that their angle of twist is the same.

Quick Tip

Remember the analogy with electrical circuits and springs: - **Shafts in Parallel:** Angle of twist (θ) is the same (like voltage in parallel). Total torque (T) is the sum (like current in parallel). - **Shafts in Series:** Torque (T) is the same (like current in series). Total angle of twist (θ) is the sum (like voltage in series).

---

88. Which of the following metals shows a clear yield point?
(A) Copper
(B) Aluminium
(C) Mild steel
(D) Titanium

Correct Answer: (C) Mild steel

Solution:
A clear or distinct yield point is a specific phenomenon observed in the stress-strain curve of certain materials, most notably low-carbon (mild) steel.

It is characterized by an upper yield point and a lower yield point. At the upper yield point, the stress required to continue deformation drops suddenly. The material then deforms under a roughly constant stress (the lower yield point) for some amount of strain before strain hardening begins.

This phenomenon is caused by the interaction of carbon atoms with dislocations in the iron crystal lattice.

Most other metals, including copper, aluminum, and titanium alloys, do not exhibit this distinct yield point phenomenon. Their stress-strain curves show a smooth transition from the elastic to the plastic region. For these materials, a "yield strength" is defined using an offset method (e.g., the 0.2

Quick Tip

When you see "clear yield point" or "upper and lower yield point," the answer is almost always mild steel or low-carbon steel. This is a unique characteristic of this material that you should memorize.

---

89. Cold working process can be applied on the components having diameter up to:
(A) 12 mm
(B) 25 mm

(C) 49 mm
(D) 50 mm

Correct Answer: (B) 25 mm

Solution:
Cold working refers to plastic deformation of a metal carried out at a temperature below its recrystallization temperature, typically at room temperature.

During cold working, the metal undergoes strain hardening, which increases its strength and hardness but reduces its ductility.

Because the material is stronger and less ductile at these temperatures, the forces required for deformation are very high.

This high force requirement places a practical limit on the size and cross-section of the components that can be cold-worked. The process is most suitable for smaller components.

While there is no single absolute limit, as it depends on the specific process (e.g., rolling, drawing, forging) and the power of the machinery, a general practical upper limit for common cold working processes on steel components is often cited in the range of a few tens of millimeters.

Among the given options, 25 mm is a reasonable and commonly accepted general limit for the diameter of components that are typically cold-worked. Larger diameters would require exceptionally large forces and are usually hot-worked instead.

Quick Tip

Cold working is generally for smaller cross-sections due to high force requirements (e.g., wires, sheets, small bars). Hot working is used for large cross-sections (e.g., I-beams, large shafts) because the high temperature makes the metal much easier to deform.

---

90. Thermal stress occurs when:
(A) Temperature is uniform
(B) Expansion is allowed
(C) Expansion is restrained
(D) There is no temperature change

Correct Answer: (C) Expansion is restrained

Solution:
Most materials expand when heated and contract when cooled. This is known as thermal expansion.

If a body is free to expand or contract, a change in temperature will cause a change in its dimensions (thermal strain), but it will not create any internal stress.

Thermal stress is only induced in a body when the thermal expansion or contraction that it wants to undergo is prevented or restrained by some external constraint.

For example, if a rod is heated but its ends are fixed between two rigid walls, the walls will prevent it from expanding. This restraint will induce a compressive stress in the rod.

Therefore, the necessary condition for the generation of thermal stress is that the thermal expansion or contraction must be restrained.

> **Quick Tip**
>
> Remember the key ingredients for thermal stress: a change in temperature PLUS a constraint or restraint. No restraint means no stress, only a change in size.

---

91. In a vapour compression refrigeration cycle, the refrigerant absorbs heat in the following.
(A) Condenser
(B) Compressor
(C) Expansion valve
(D) Evaporator

Correct Answer: (D) Evaporator

Solution:
The vapour compression refrigeration cycle consists of four main components: compressor, condenser, expansion valve, and evaporator.

The purpose of a refrigeration system is to remove heat from a cold space.

This heat absorption process occurs in the evaporator.

In the evaporator, the low-pressure, low-temperature liquid refrigerant absorbs heat from the surrounding space (the area to be cooled).

This absorption of heat causes the refrigerant to boil and change its phase from a liquid to a vapor. This is the "refrigeration effect".

The condenser, in contrast, is where the refrigerant rejects heat to the surroundings.

> **Quick Tip**
>
> Remember the functions of the 4 main components: - **Evaporator:** Absorbs heat (cools the space). - **Compressor:** Increases pressure and temperature of the vapor. - **Condenser:** Rejects heat (cools the refrigerant). - **Expansion Valve:** Reduces pressure and temperature of the liquid.

---

92. Group technology brings together and organizes:
(A) Parts and simulation analysis
(B) Documentation and analysis
(C) Automation and tool production
(D) Common parts, problems, and tasks

Correct Answer: (D) Common parts, problems, and tasks

Solution:
Group Technology (GT) is a manufacturing philosophy based on the principle of identifying and exploiting similarities among parts.

The core idea is that many problems are similar, and by grouping similar problems, a single solution can be found for a set of problems, thus saving time and effort.

In manufacturing, GT involves:
1. Identifying parts with similar design attributes (e.g., shape, size) or manufacturing attributes (e.g., the sequence of operations required).
2. Grouping these similar parts into "part families".
3. Organizing the manufacturing facility into "machine cells" to produce these part families.

This approach effectively brings together and organizes common parts, and the common problems and tasks associated with their production.

> **Quick Tip**
>
> The motto of Group Technology is "find similarity and group things". By grouping similar parts into families, you can use cellular manufacturing to improve efficiency, reduce setup times, and simplify production planning.

93. Forging is typically done:
(A) At room temperature
(B) At elevated temperatures
(C) In powder form
(D) For non-metallic parts

Correct Answer: (A) At room temperature

Solution:
Forging is a manufacturing process involving the shaping of metal using localized compressive forces. It can be performed at different temperatures.

- **Hot Forging:** Performed at temperatures above the metal's recrystallization temperature. Requires less force and can create complex shapes.
- **Cold Forging:** Performed at or near room temperature. It requires higher forces but results in better surface finish, dimensional accuracy, and increased strength through strain hardening.

Both methods are widely used. Cold forging is a "typical" method for the mass production of smaller, high-precision parts like fasteners (bolts, screws), and automotive components. Since cold forging is done at room temperature, this option is a valid description of a major category of forging operations. Given the available choices, this is the intended answer.

Quick Tip

While hot forging is common for large parts, cold forging is extremely common for mass-producing smaller parts with high precision. Both are "typical". In an exam, if you must choose one, consider the context or the common application of producing high-volume standard parts, which often favors cold forging.

---

94. With rise in gas temperature, dynamic viscosity of most of the gases:
(A) Increases
(B) Decreases
(C) Does not change significantly.
(D) Remains constant

Correct Answer: (A) Increases

Solution:
The mechanism of viscosity is different for liquids and gases.

- In **liquids**, viscosity is primarily due to cohesive forces between molecules. As temperature increases, these forces weaken, and the molecules can move past each other more easily, so the viscosity decreases.

- In **gases**, molecules are far apart, and cohesive forces are negligible. Viscosity is primarily due to the random motion of molecules and the transfer of momentum through molecular collisions.

As the temperature of a gas increases, the random thermal motion of its molecules increases. This leads to more frequent and energetic collisions, resulting in a greater transfer of momentum between adjacent layers of gas. This increased momentum transfer manifests as an increase in the dynamic viscosity.

Quick Tip

Remember the opposite trends for viscosity and temperature: - **Liquids:** Temperature $\uparrow \implies$ Viscosity $\downarrow$. - **Gases:** Temperature $\uparrow \implies$ Viscosity $\uparrow$.

---

95. Conduction requires:
(A) Temperature gradient
(B) Fluid motion
(C) Radiation
(D) Vacuum

Correct Answer: (A) Temperature gradient

Solution:
Heat transfer is the movement of thermal energy from one place to another. There are three modes of heat transfer: conduction, convection, and radiation.

Conduction is the transfer of heat through direct contact of particles within a substance or between two substances in contact.

The fundamental law governing conduction is Fourier's Law of Heat Conduction, which states that the rate of heat transfer is proportional to the area normal to the heat flow and the temperature gradient in that direction.
$Q = -kA\frac{dT}{dx}$

This equation shows that for heat transfer (Q) to occur, there must be a temperature gradient ($\frac{dT}{dx}$). If the temperature is uniform, the gradient is zero, and there is no net heat conduction.

Fluid motion is required for convection. Radiation can travel through a vacuum.

Quick Tip

The "driving force" for the three modes of heat transfer are: - **Conduction:** Temperature Gradient. - **Convection:** Temperature Difference (and fluid motion). - **Radiation:** Difference in the fourth power of absolute temperatures.

---

96. A system of masses rotating in different parallel planes is in dynamic balance if the resultant:
(A) Force is equal to zero
(B) Couple is equal to zero
(C) Force and the resultant couple are both equal to zero
(D) Force is numerically equal to the resultant couple, but neither of them need necessarily be zero.

Correct Answer: (C) Force and the resultant couple are both equal to zero

Solution:
For a rotating system to be completely balanced, it must be in both static and dynamic balance.

Static Balance: This condition requires that the net centrifugal force due to all the rotating masses is zero ($\Sigma\vec{F} = 0$). If a rotor is statically balanced, it will not rotate under the influence of gravity when placed on level knife-edges. This condition eliminates shaking forces on the bearings.

Dynamic Balance: This condition arises because unbalanced masses can create a turning moment, or couple, on the rotor. For dynamic balance, the net couple due to the centrifugal forces must also be zero ($\Sigma\vec{M} = 0$). This condition eliminates wobbling or rocking moments on the bearings.

A system is said to be in complete dynamic balance only when both the resultant force and the resultant couple are zero.

Quick Tip

Dynamic balance is the all-encompassing condition. If a rotor is dynamically balanced, it is automatically statically balanced. However, a statically balanced rotor is not necessarily dynamically balanced.

---

97. Ability of a material to retain the deformation permanently is called:
(A) Stiffness
(B) Ductility

(C) Hardness
(D) Plasticity

Correct Answer: (D) Plasticity

Solution:
Mechanical properties describe how a material responds to applied forces.

When a material is deformed, the deformation can be either elastic or plastic.
- **Elastic deformation** is temporary. When the load is removed, the material returns to its original shape.
- **Plastic deformation** is permanent. When the load is removed, the material does not return to its original shape; it retains some or all of the deformation.

The ability of a material to undergo this permanent deformation without rupturing is called **plasticity**.

Stiffness is the resistance to elastic deformation. Ductility is a measure of the degree of plastic deformation a material can sustain before fracture. Hardness is resistance to surface indentation.

Quick Tip

Think of the difference between a spring and a piece of clay. A spring is highly elastic (it returns to its shape). Clay is highly plastic (it retains its new shape permanently).

---

98. The creep in belt drive is due to the:
(A) Material of the pulleys
(B) Material of the belt
(C) Unequal size of the pulleys
(D) Unequal tension on tight side and slack sides of the belt

Correct Answer: (D) Unequal tension on tight side and slack sides of the belt

Solution:
In a belt drive that is transmitting power, the tension in the belt is not uniform. The portion of the belt moving towards the driver pulley is under low tension (the slack side, T_2), and the portion moving away from the driver pulley is under high tension (the tight side, T_1).

Because the belt material is elastic, it stretches and contracts as the tension changes.

As a segment of the belt travels around the driver pulley, its tension increases from T_2 to T_1, causing it to stretch.
As the same segment travels around the driven pulley, its tension decreases from T_1 to T_2, causing it to contract.

This continuous change in length results in a slight relative motion between the belt and the pulley surface. This phenomenon is called creep.

Therefore, creep is a direct consequence of the unequal tensions required for power transmission.

Quick Tip

Do not confuse creep with slip. **Creep** is due to the elasticity of the belt and the difference in tensions; it is unavoidable during power transmission. **Slip** is due to insufficient friction between the belt and pulley, often caused by overload or low initial tension, and it results in a larger loss of speed.

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99. Spur gears have:
(A) Helical teeth
(B) Straight teeth
(C) Bevel teeth
(D) Spiral teeth

Correct Answer: (B) Straight teeth

Solution:
Gears are classified based on the orientation of their teeth relative to the axis of the gear.

Spur gears are the simplest and most common type of gear.

By definition, the teeth of a spur gear are straight and cut parallel to the axis of rotation of the gear.

They are used to transmit power between two parallel shafts.

Helical gears have teeth that are cut at an angle (the helix angle) to the axis. Bevel and spiral gears are used for non-parallel shafts.

Quick Tip

Picture a simple can (like a soup can). If you cut grooves straight down the side, parallel to its height, those are like spur gear teeth. If you cut them at an angle, like the stripes on a candy cane, those are like helical gear teeth.

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100. A flow in which each liquid particle has a definite path and their paths do not cross each other, is called:
(A) Steady flow
(B) Uniform flow
(C) Streamline flow
(D) Turbulent flow

Correct Answer: (C) Streamline flow

Solution:
This question describes the characteristics of different types of fluid flow.

The path traced by a single fluid particle is called a pathline.

A streamline is an imaginary curve drawn in a flow field such that the tangent to it at any point gives the direction of the velocity vector at that point.

In a **streamline flow** (also known as laminar flow), the fluid moves in smooth, parallel layers, or laminae. The pathlines of individual particles do not cross one another. The flow is orderly.

In **turbulent flow**, the fluid particles move in a chaotic and irregular manner, with the formation of eddies. The pathlines of particles are highly irregular and cross each other extensively.

Steady flow refers to a condition where fluid properties at a point do not change with time. Uniform flow refers to a condition where the velocity is the same at all points in the flow at a given instant.

The definition given in the question perfectly matches that of streamline flow.

Quick Tip

Remember the key visual difference: **Streamline/Laminar Flow:** Smooth, orderly, parallel layers (like a slow-moving river). **Turbulent Flow:** Chaotic, swirling, eddies (like a fast-moving, whitewater rapids).

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101. Heat conduction through a wall follows:
(A) Fourier's law
(B) Newton's law
(C) Stefan-Boltzmann law
(D) Kirchhoff's law

Correct Answer: (A) Fourier's law

Solution:
The fundamental principle governing the rate of heat transfer by conduction is Fourier's Law.

Fourier's Law states that the rate of heat transfer through a material is proportional to the negative gradient in the temperature and to the area at right angles to that gradient through which the heat flows.

For one-dimensional heat conduction through a plane wall, the law is expressed as:
$Q_{cond} = -kA\frac{dT}{dx}$

Where Q_{cond} is the rate of heat transfer, k is the thermal conductivity, A is the cross-sectional area, and $\frac{dT}{dx}$ is the temperature gradient.

The other laws are for different phenomena: - Newton's law of cooling is for convection. - Stefan-Boltzmann law is for radiation. - Kirchhoff's law relates emissivity and absorptivity in radiation.

Quick Tip

Associate the fundamental laws with the modes of heat transfer: - **Conduction** $\rightarrow$ **Fourier's Law**. - **Convection** $\rightarrow$ **Newton's Law of Cooling**. - **Radiation** $\rightarrow$ **Stefan-Boltzmann Law**.

---

102. If the efficiency of a belt drive is more than 50, then it is called:
(A) Self-locking
(B) Over loading
(C) Over-hauling
(D) Over efficiency drive

Correct Answer: (C) Over-hauling

Solution:
This question applies the concepts of self-locking and over-hauling, which are typically dis-

cussed in the context of screw jacks, to a belt drive.

In a machine, let the effort be P and the load be W. The efficiency (η) is the ratio of the ideal effort to the actual effort.

- **Self-locking:** A machine is self-locking if the load cannot drive the machine backwards (i.e., the load cannot overcome friction to cause motion). This condition occurs when the efficiency of the machine is less than 50% ($\eta < 50\%$).

- **Over-hauling (or Reversible):** A machine is over-hauling if the load is able to drive the machine backwards. This condition occurs when the efficiency of the machine is greater than 50% ($\eta > 50\%$).

The question states that the efficiency of the belt drive is more than 50%. Based on the definitions above, the drive is said to be over-hauling or reversible.

Quick Tip

The 50% efficiency mark is the critical point for reversibility in machines like screw jacks and worm gears. - **Efficiency ¡ 50%**: Self-locking (friction is large enough to hold the load). - **Efficiency ¿ 50%**: Over-hauling (load will cause the machine to run backwards if the effort is removed).

---

103. Discontinuous chips are formed during machining of:
(A) Cast iron
(B) Mild steel
(C) Aluminium
(D) Stainless steel

Correct Answer: (A) Cast iron

Solution:
The type of chip formed in a machining process is highly dependent on the ductility of the workpiece material.

Discontinuous chips consist of small, segmented pieces. They are formed when the material being machined is brittle. In brittle materials, plastic deformation is limited. As the tool applies stress, the material fractures ahead of the tool tip, creating a segment of the chip, and the process repeats.

- **Cast iron** is a classic example of a brittle material. Machining cast iron typically produces small, crumbly, discontinuous chips.

- Mild steel, aluminum, and stainless steel are all ductile materials. When machined under normal conditions, they form long, continuous, ribbon-like chips.

Therefore, discontinuous chips are formed during the machining of cast iron.

Quick Tip

Chip Type vs. Material Ductility: - **Brittle Material** (e.g., Cast Iron, Brass) → **Discontinuous Chips**. - **Ductile Material** (e.g., Steel, Aluminum) → **Continuous Chips**.

---

104. Limits and fits ensure:
(A) Aesthetic appeal
(B) Proper function and interchangeability
(C) Heat transfer
(D) Colour coding

Correct Answer: (B) Proper function and interchangeability

Solution:
The system of limits and fits is a fundamental concept in engineering design and manufacturing.

It involves defining a range of allowable dimensions (a tolerance) for a part, rather than a single exact dimension. A "fit" describes the relationship between two mating parts (like a shaft and a hole) resulting from the difference in their sizes before assembly.

The two primary goals of using a system of limits and fits are:
1. **Proper Function:** By specifying the type of fit (e.g., clearance, transition, or interference), the designer can ensure that the assembled parts will function as intended. For example, a shaft must have a clearance fit to rotate freely in a bearing, while a pin might need an interference fit to stay securely in a hole.

2. **Interchangeability:** By manufacturing all parts within their specified tolerance zones, any randomly selected shaft will assemble and function correctly with any randomly selected hole. This is the basis of mass production, as it eliminates the need for selective, hand-fitting of parts.

Quick Tip

Limits and fits are the backbone of modern mass production. They guarantee that parts made in different places at different times can be assembled together without issue, ensuring both functionality and interchangeability.

105. For maximum horizontal range, the angle of projection of a projectile should be:
(A) 30°
(B) 45°
(C) 60°
(D) 90°

Correct Answer: (B) 45°

Solution:
The formula for the horizontal range (R) of a projectile launched from and landing on the same horizontal level is:
$R = \frac{v_0^2 \sin(2\theta)}{g}$

Where v_0 is the initial velocity, θ is the projection angle, and g is the acceleration due to gravity.

To maximize the range R for a given initial velocity v_0, we need to maximize the term $\sin(2\theta)$.

The maximum value of the sine function is 1.
$\sin(2\theta) = 1$

This occurs when the angle of the sine function is 90°.
$2\theta = 90°$

Solving for the projection angle θ:
$\theta = \frac{90°}{2} = 45°$

Therefore, the maximum horizontal range is achieved at a projection angle of 45°.

Quick Tip

For projectile motion on level ground: - **Maximum Range:** Angle = 45°. - **Maximum Height:** Angle = 90° (fired straight up). - The range is the same for complementary angles (e.g., 30° and 60°).

106. Francis, Kaplan and propeller turbines fall under the category of:
(A) Reaction turbines
(B) Impulse turbines
(C) Axial flow turbines
(D) Mixed flow turbines

Correct Answer: (A) Reaction turbines

Solution:
Hydraulic turbines are broadly classified into two main categories based on their principle of operation: Impulse turbines and Reaction turbines.

- **Impulse Turbines:** In these turbines, all the available potential energy of the water is converted into kinetic energy in a nozzle before it strikes the turbine blades. The pressure of the water is atmospheric as it flows over the blades. The only example is the Pelton wheel.

- **Reaction Turbines:** In these turbines, only a portion of the available potential energy is converted into kinetic energy before the water enters the runner. The water flows through the runner under pressure. The pressure drops as the water passes through the blades, and this pressure drop creates a reaction force that drives the turbine.

Francis, Kaplan, and Propeller turbines all operate on this principle. The water enters the runner under pressure, and both pressure and velocity change as it passes through. Therefore, they are all reaction turbines.

Quick Tip

Easy classification for hydraulic turbines: - **Impulse Turbine** = Pelton Wheel. - **Reaction Turbines** = Francis, Kaplan, Propeller. Think of "Reaction" as having a pressure drop across the blades.

---

107. Bernoulli's equation is applicable to:
(A) Compressible viscous flows
(B) All types of flow
(C) Incompressible and inviscid flow
(D) Steady turbulent flows

Correct Answer: (C) Incompressible and inviscid flow

Solution:
Bernoulli's equation, $P + \frac{1}{2}\rho V^2 + \rho g z =$ constant, is a statement of the conservation of energy for a moving fluid.

However, it is derived based on several key assumptions, which limit its applicability. The main assumptions are:
1. The flow is **steady** (fluid properties at a point do not change with time).
2. The flow is **inviscid** (viscous forces are negligible, meaning no friction).
3. The flow is **incompressible** (density ρ is constant).

4. The equation is applied along a streamline.

Options (A) and (D) are incorrect because the equation requires inviscid (non-viscous) flow. Option (B) is incorrect because the equation is not universally applicable.

Option (C) correctly lists two of the most important conditions: the fluid must be treated as incompressible (constant density) and inviscid (frictionless).

Quick Tip

Remember the four key assumptions for Bernoulli's equation: **S**teady, **I**ncompressible, **I**nviscid, and along a **S**treamline. (Mnemonic: SIIS). Any deviation from these assumptions means the standard Bernoulli equation does not apply.

---

108. The area enclosed by a thermodynamic cycle on a p-v diagram represents:
(A) Heat rejected
(B) Net work done
(C) Energy loss
(D) Efficiency

Correct Answer: (B) Net work done

Solution:
In thermodynamics, the work done during a quasi-static process is given by the integral of pressure with respect to volume: $W = \int P\,dV$.

Geometrically, this integral represents the area under the process curve on a Pressure-Volume (p-v) diagram.

A thermodynamic cycle is a series of processes that returns the system to its initial state. It forms a closed loop on a p-v diagram.

The work done during the expansion part of the cycle is positive (work done by the system) and is the area under the expansion curve.
The work done during the compression part of the cycle is negative (work done on the system) and is the area under the compression curve.

The net work done during the entire cycle is the difference between the work of expansion and the work of compression. Geometrically, this is exactly equal to the area enclosed by the cycle's loop on the p-v diagram.

Quick Tip

For diagrams in thermodynamics: - Area under a curve on a **p-v diagram** = Work (W). - Area under a curve on a **T-s diagram** = Heat transfer (Q). The area *enclosed by a cycle* on either diagram represents the net quantity (net work or net heat).

---

109. In electrical resistance welding, pressure applied varies in the range:
(A) 50 to 100 kgf/cm^2
(B) 100 to 200 kgf/cm^2
(C) 250 to 550 kgf/cm^2
(D) 600 to 900 kgf/cm^2

Correct Answer: (C) 250 to 550 kgf/cm^2

Solution:
Electrical resistance welding (ERW) is a group of welding processes (like spot, seam, and projection welding) that use a combination of heat and pressure to join metals.

The heat is generated by the resistance of the workpieces to the flow of a large electric current. The pressure has two main functions:
1. To hold the workpieces in intimate contact before and during the welding to ensure a good electrical path.
2. To forge the heated, plasticized metal together to form a solid weld nugget as the current is turned off and the metal cools.

The magnitude of the pressure is critical. It must be high enough to forge the parts together but not so high that it expels all the molten metal from the weld zone.

The typical range for the applied pressure in processes like spot welding and projection welding is quite high. For materials like low-carbon steel, the electrode pressure generally falls within the range of 250 to 550 kgf/cm^2. This range ensures a sound weld without excessive indentation or expulsion.

Quick Tip

Resistance welding relies on two key parameters: high current (for heat) and high pressure (for forging). Remember that the pressure is substantial, typically in the hundreds of kgf/cm^2, to properly forge the weld nugget.

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110. Compared to the Otto cycle for the same compression ratio, the diesel cycle efficiency is:

(A) Lower
(B) Higher
(C) Equal
(D) Cannot be determined

Correct Answer: (A) Lower

Solution:
The thermal efficiency of the Otto cycle is given by:
$\eta_{Otto} = 1 - \frac{1}{r^{\gamma-1}}$

The thermal efficiency of the Diesel cycle is given by:
$\eta_{Diesel} = 1 - \frac{1}{r^{\gamma-1}} \left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$

Here, 'r' is the compression ratio, 'γ' is the ratio of specific heats, and 'ρ' is the cut-off ratio ($\rho > 1$).

Let's compare the two formulas for the same compression ratio 'r' and the same working fluid 'γ'.
$\eta_{Diesel} = \eta_{Otto} \times \frac{1}{\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]}$
The term in the bracket, $\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$, is always greater than 1 for $\rho > 1$.

Therefore, the diesel cycle efficiency formula is equal to the Otto cycle efficiency formula multiplied by a factor that is less than 1.

This means that for the same compression ratio, the efficiency of the Diesel cycle is always lower than the efficiency of the Otto cycle.
$\eta_{Diesel} < \eta_{Otto}$ (for the same 'r').

Quick Tip

For cycle efficiency comparisons: - **Same Compression Ratio and Heat Input:** $\eta_{Otto} > \eta_{Dual} > \eta_{Diesel}$. - **Same Maximum Pressure and Temperature:** $\eta_{Diesel} > \eta_{Dual} > \eta_{Otto}$. It's crucial to note the basis of comparison.

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111. Determine the value of λ and μ for which such that the system of equations x + 2y + z = 6, x + 4y + 3z = 10, and 2x + 4y + λz = μ has infinite number of solutions
(A) $\lambda = 2, \mu \neq 12$
(B) $\lambda = 2, \mu = 12$
(C) $\lambda \neq 2, \mu \neq 12$

(D) for any λ and any μ

Correct Answer: (B) $\lambda = 2, \mu = 12$

Solution:
For a system of linear equations to have an infinite number of solutions, the rank of the coefficient matrix (A) must be equal to the rank of the augmented matrix ([A—B]), and this rank must be less than the number of variables.

The augmented matrix for the system is:
$$[A|B] = \begin{pmatrix} 1 & 2 & 1 & | & 6 \\ 1 & 4 & 3 & | & 10 \\ 2 & 4 & \lambda & | & \mu \end{pmatrix}$$
Let's perform row operations to get it into row-echelon form.
$R_2 \to R_2 - R_1$
$R_3 \to R_3 - 2R_1$
$$\begin{pmatrix} 1 & 2 & 1 & | & 6 \\ 0 & 2 & 2 & | & 4 \\ 0 & 0 & \lambda - 2 & | & \mu - 12 \end{pmatrix}$$
For the system to have infinite solutions, the last row must be all zeros. This ensures that rank(A) = rank([A—B]) ¡ 3.
This requires two conditions to be met simultaneously:
1. The coefficient of z must be zero: $\lambda - 2 = 0 \implies \lambda = 2$.
2. The constant term on the right side must be zero: $\mu - 12 = 0 \implies \mu = 12$.

Therefore, the system has infinite solutions only when $\lambda = 2$ and $\mu = 12$.

Quick Tip

For a system of 3 linear equations in 3 variables: - **Unique Solution:** rank(A) = rank([A—B]) = 3. - **Infinite Solutions:** rank(A) = rank([A—B]) ¡ 3. (Last row of echelon form is 0 0 0 — 0). - **No Solution:** rank(A) $\neq$ rank([A—B]). (Last row of echelon form is 0 0 0 — non-zero).

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112. If the matrix A = $\begin{pmatrix} 3 & -1 & 1 \\ -1 & 5 & -1 \\ 1 & -1 & 3 \end{pmatrix}$ **has three distinct eigenvalues and one of its eigenvectors is** $\begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix}$**, then which of the following can be another eigenvector of A?**

(A) $\begin{pmatrix} -1 \\ 0 \\ 1 \end{pmatrix}$

(B) $\begin{pmatrix} -1 \\ 0 \\ 2 \end{pmatrix}$

(C) $\begin{pmatrix} 1 \\ 1 \\ -1 \end{pmatrix}$

(D) $\begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}$

Correct Answer: (D) $\begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}$

Solution:
The given matrix A is a real symmetric matrix ($A = A^T$).
A key property of real symmetric matrices is that their eigenvectors corresponding to distinct eigenvalues are orthogonal.

Let the given eigenvector be $X_1 = \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix}$.
Let another eigenvector corresponding to a different eigenvalue be X_2.
For the eigenvectors to be orthogonal, their dot product must be zero: $X_1^T X_2 = 0$.

Let's test the dot product of X_1 with each of the options.

(A) $\begin{pmatrix} 1 & 0 & -1 \end{pmatrix} \begin{pmatrix} -1 \\ 0 \\ 1 \end{pmatrix} = (1)(-1) + (0)(0) + (-1)(1) = -1 - 1 = -2 \neq 0.$ Not orthogonal.

(B) $\begin{pmatrix} 1 & 0 & -1 \end{pmatrix} \begin{pmatrix} -1 \\ 0 \\ 2 \end{pmatrix} = (1)(-1) + (0)(0) + (-1)(2) = -1 - 2 = -3 \neq 0.$ Not orthogonal.

(C) $\begin{pmatrix} 1 & 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 1 \\ -1 \end{pmatrix} = (1)(1) + (0)(1) + (-1)(-1) = 1 + 1 = 2 \neq 0.$ Not orthogonal.

(D) $\begin{pmatrix} 1 & 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix} = (1)(1) + (0)(-2) + (-1)(1) = 1 - 1 = 0.$ Orthogonal.

Since the vector in option (D) is orthogonal to the given eigenvector, it can be another eigenvector of the symmetric matrix A.

Quick Tip

The most important property for this problem: Eigenvectors of a real symmetric matrix corresponding to distinct eigenvalues are always orthogonal. When you see a symmetric matrix in an eigenvector problem, immediately check for orthogonality.

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113. If $\vec{F} = x(x^2 + y^2 + z^2)\hat{i} + 2y(x^2 + y^2 + z^2)\hat{j} + 3z(x^2 + y^2 + z^2)\hat{k}$, then div$\vec{F}$ at (1,1,1) is equal to
(A) 12
(B) 21
(C) 30
(D) 33

Correct Answer: (C) 30

Solution:
Let the vector field be $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$.
The components are:
$F_x = x(x^2 + y^2 + z^2) = x^3 + xy^2 + xz^2$
$F_y = 2y(x^2 + y^2 + z^2) = 2yx^2 + 2y^3 + 2yz^2$
$F_z = 3z(x^2 + y^2 + z^2) = 3zx^2 + 3zy^2 + 3z^3$

The divergence of $\vec{F}$ is given by div$\vec{F} = \nabla \cdot \vec{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}$.

Calculate the partial derivatives:
$\frac{\partial F_x}{\partial x} = 3x^2 + y^2 + z^2$
$\frac{\partial F_y}{\partial y} = 2x^2 + 6y^2 + 2z^2$
$\frac{\partial F_z}{\partial z} = 3x^2 + 3y^2 + 9z^2$

Sum the partial derivatives to get the divergence:
div$\vec{F} = (3x^2 + y^2 + z^2) + (2x^2 + 6y^2 + 2z^2) + (3x^2 + 3y^2 + 9z^2)$
div$\vec{F} = 8x^2 + 10y^2 + 12z^2$

Now, evaluate the divergence at the point (1, 1, 1):
div$\vec{F}|_{(1,1,1)} = 8(1)^2 + 10(1)^2 + 12(1)^2$
div$\vec{F}|_{(1,1,1)} = 8 + 10 + 12 = 30$.

Quick Tip

Remember the formula for divergence: div$\vec{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}$. It's a scalar quantity obtained by taking the dot product of the del operator (∇) with the vector field ($\vec{F}$).

114. The value of the line integral $\int_C (2xy^2dx + 2x^2ydy - \frac{1}{3}zdz)$ along a path joining the origin (0,0,0) and the point (1,1,1) is

(A) 1/2
(B) 7/6
(C) 3/2
(D) 5/6

Correct Answer: (D) 5/6

Solution:
The given line integral is of the form $\int_C \vec{F} \cdot d\vec{r}$, where $\vec{F} = (2xy^2)\hat{\imath} + (2x^2y)\hat{\jmath} - (\frac{1}{3}z)\hat{k}$.
First, let's check if the vector field $\vec{F}$ is conservative by checking if its curl is zero.
Curl$\vec{F} = \nabla \times \vec{F} = \begin{vmatrix} \hat{\imath}\&\hat{\jmath}\&\hat{k} \\ \frac{\partial}{\partial x}\&\frac{\partial}{\partial y}\&\frac{\partial}{\partial z} \\ 2xy^2\&2x^2y\&-\frac{1}{3}z \end{vmatrix}$
$= \hat{\imath}(0-0) - \hat{\jmath}(0-0) + \hat{k}(4xy - 4xy) = \vec{0}$.
Since the curl is zero, the field is conservative, and the line integral is path-independent. We can find a potential function ϕ such that $\vec{F} = \nabla\phi$.
$\frac{\partial \phi}{\partial x} = 2xy^2 \implies \phi = \int 2xy^2 dx = x^2y^2 + f(y,z)$.
$\frac{\partial \phi}{\partial y} = 2x^2y + \frac{\partial f}{\partial y} = 2x^2y \implies \frac{\partial f}{\partial y} = 0 \implies f = g(z)$. So, $\phi = x^2y^2 + g(z)$.
$\frac{\partial \phi}{\partial z} = g'(z) = -\frac{1}{3}z \implies g(z) = \int -\frac{1}{3}zdz = -\frac{z^2}{6}$.
The potential function is $\phi(x,y,z) = x^2y^2 - \frac{z^2}{6}$.

By the fundamental theorem of line integrals, the value of the integral is $\phi(\text{end point}) - \phi(\text{start point})$.
Start point: (0,0,0). End point: (1,1,1).
Value $= \phi(1,1,1) - \phi(0,0,0)$
$= \left((1)^2(1)^2 - \frac{(1)^2}{6}\right) - \left((0)^2(0)^2 - \frac{(0)^2}{6}\right)$
$= \left(1 - \frac{1}{6}\right) - 0 = \frac{5}{6}$.

Quick Tip

Before calculating a line integral, always check if the vector field is conservative by calculating its curl. If the curl is zero, the integral is path-independent. You can then find a potential function ϕ and simply evaluate $\phi(\text{end}) - \phi(\text{start})$, which is usually much easier than parametrizing a path.

115. If y(x) satisfies the differential equation $x\frac{dy}{dx} + (x-y) = 0$ subject to the condition y(1)=0, then y(e) is

(A) -e
(B) -2e
(C) e
(D) 2e

Correct Answer: (A) -e

Solution:
The given differential equation is $x\frac{dy}{dx} + (x - y) = 0$.
Let's rearrange it into the standard form for a linear first-order ODE: $\frac{dy}{dx} + P(x)y = Q(x)$.
$x\frac{dy}{dx} - y = -x$
$\frac{dy}{dx} - \frac{1}{x}y = -1$
This is a linear ODE with $P(x) = -1/x$ and $Q(x) = -1$.

Calculate the integrating factor (I.F.):
I.F. $= e^{\int P(x)dx} = e^{\int -1/xdx} = e^{-\ln(x)} = e^{\ln(x^{-1})} = x^{-1} = \frac{1}{x}$.

The solution is given by $y \cdot \text{(I.F.)} = \int Q(x) \cdot \text{(I.F.)}dx + C$.
$y \cdot \frac{1}{x} = \int (-1) \cdot \frac{1}{x}dx + C$
$\frac{y}{x} = -\ln(x) + C$
$y(x) = -x\ln(x) + Cx$

Now, apply the initial condition y(1) = 0 to find C.
$0 = -1\ln(1) + C(1)$
$0 = -1(0) + C \implies C = 0$.

So the particular solution is $y(x) = -x\ln(x)$.

Finally, find the value of y(e).
$y(e) = -e\ln(e)$
Since $\ln(e) = 1$,
$y(e) = -e(1) = -e$.

Quick Tip

To solve a first-order linear differential equation of the form $y' + P(x)y = Q(x)$, first find the integrating factor $I(x) = e^{\int P(x)dx}$. The solution is then given by $y \cdot I(x) = \int Q(x) \cdot I(x)dx$.

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116. If the Laplace transform of a function f(t) is given by $\frac{2s+1}{(s+1)(s+2)}$, then f(0) is equal to
(A) 2

(B) 4
(C) -4
(D) 3e-1

Correct Answer: (A) 2

Solution:
The Initial Value Theorem of Laplace transforms states that if $F(s)$ is the Laplace transform of $f(t)$, then the initial value $f(0)$ can be found using the limit:
$f(0) = \lim_{t \to 0} f(t) = \lim_{s \to \infty} sF(s)$

Given $F(s) = \frac{2s+1}{(s+1)(s+2)}$.

Now, we apply the theorem:
$f(0) = \lim_{s \to \infty} s\left(\frac{2s+1}{(s+1)(s+2)}\right)$
$f(0) = \lim_{s \to \infty} \frac{s(2s+1)}{s^2+3s+2}$
$f(0) = \lim_{s \to \infty} \frac{2s^2+s}{s^2+3s+2}$

To evaluate the limit as $s \to \infty$, we can divide the numerator and the denominator by the highest power of s, which is s^2.
$f(0) = \lim_{s \to \infty} \frac{\frac{2s^2}{s^2}+\frac{s}{s^2}}{\frac{s^2}{s^2}+\frac{3s}{s^2}+\frac{2}{s^2}}$
$f(0) = \lim_{s \to \infty} \frac{2+\frac{1}{s}}{1+\frac{3}{s}+\frac{2}{s^2}}$

As $s \to \infty$, the terms $\frac{1}{s}$, $\frac{3}{s}$, and $\frac{2}{s^2}$ all approach 0.
$f(0) = \frac{2+0}{1+0+0} = 2$.

Quick Tip

Remember the Initial and Final Value Theorems: - **Initial Value Theorem:** $f(0) = \lim_{s \to \infty} sF(s)$ - **Final Value Theorem:** $\lim_{t \to \infty} f(t) = \lim_{s \to 0} sF(s)$ They provide a quick way to find the initial and final values of a function directly from its Laplace transform.

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117. Let A, B be two events and $\bar{A}$ be the complement of A. If $P(\bar{A}) = 0.7, P(B) = 0.7$ and $P(B|A) = 0.5$, then $P(A \cup B) =$
(A) 0.65
(B) 0.85
(C) 0.75
(D) 0.50

Correct Answer: (B) 0.85

Solution:
We are given the following probabilities:
$P(\bar{A}) = 0.7$
$P(B) = 0.7$
$P(B|A) = 0.5$

First, let's find $P(A)$.
$P(A) = 1 - P(\bar{A}) = 1 - 0.7 = 0.3$.

Next, let's find $P(A \cap B)$ using the formula for conditional probability: $P(B|A) = \frac{P(A \cap B)}{P(A)}$.
$P(A \cap B) = P(B|A) \times P(A) = 0.5 \times 0.3 = 0.15$.

Now, we can use the addition rule for probability to find $P(A \cup B)$.
$P(A \cup B) = P(A) + P(B) - P(A \cap B)$
$P(A \cup B) = 0.3 + 0.7 - 0.15$
$P(A \cup B) = 1.0 - 0.15 = 0.85$.

Quick Tip

This problem requires chaining three fundamental probability formulas: 1. Complement Rule: $P(A) = 1 - P(\bar{A})$. 2. Conditional Probability: $P(A \cap B) = P(B|A) \cdot P(A)$. 3. Addition Rule: $P(A \cup B) = P(A) + P(B) - P(A \cap B)$.

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118. A machine produces 0, 1 or 2 defective items in a day with probabilities of $\frac{1}{4}, \frac{1}{2}, \frac{1}{4}$ respectively. Then, the standard deviation of the number of defective items produced by the machine in a day, is
(A) $\frac{1}{2}$
(B) $\frac{1}{\sqrt{2}}$
(C) $\frac{1}{4}$
(D) 1

Correct Answer: (B) $\frac{1}{\sqrt{2}}$

Solution:
Let X be the random variable representing the number of defective items. The probability distribution is given as: $P(X = 0) = 1/4$ $P(X = 1) = 1/2$ $P(X = 2) = 1/4$

First, calculate the mean (Expected Value), $E(X)$.
$E(X) = \sum x \cdot P(x) = (0 \times \frac{1}{4}) + (1 \times \frac{1}{2}) + (2 \times \frac{1}{4})$

$E(X) = 0 + \frac{1}{2} + \frac{2}{4} = \frac{1}{2} + \frac{1}{2} = 1.$

Next, calculate the variance, $\text{Var}(X) = E(X^2) - [E(X)]^2$.
We need to find $E(X^2)$.
$E(X^2) = \sum x^2 \cdot P(x) = (0^2 \times \frac{1}{4}) + (1^2 \times \frac{1}{2}) + (2^2 \times \frac{1}{4})$
$E(X^2) = (0 \times \frac{1}{4}) + (1 \times \frac{1}{2}) + (4 \times \frac{1}{4}) = 0 + \frac{1}{2} + 1 = 1.5 = \frac{3}{2}.$

Now, calculate the variance:
$\text{Var}(X) = E(X^2) - [E(X)]^2 = \frac{3}{2} - (1)^2 = \frac{3}{2} - 1 = \frac{1}{2}.$

Finally, the standard deviation (σ) is the square root of the variance.
$\sigma = \sqrt{\text{Var}(X)} = \sqrt{\frac{1}{2}} = \frac{1}{\sqrt{2}}.$

Quick Tip

To find the standard deviation of a discrete random variable: 1. Calculate the mean: $\mu = E(X) = \sum xP(x)$. 2. Calculate the expectation of the square: $E(X^2) = \sum x^2 P(x)$. 3. Calculate the variance: $\text{Var}(X) = E(X^2) - \mu^2$. 4. Take the square root: $\sigma = \sqrt{\text{Var}(X)}$.

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119. Evaluation of the integral $\int_2^4 x^2 dx$ using the trapezoidal rule (with two equal segments) gives a value of
(A) 14.5
(B) 22.5
(C) 19.0
(D) 18.6

Correct Answer: (C) 19.0

Solution:
We need to evaluate the integral $\int_2^4 x^2 dx$ using the composite trapezoidal rule with $n = 2$ segments.
The limits are $a = 2$ and $b = 4$. The width of each segment is $h = \frac{b-a}{n} = \frac{4-2}{2} = 1$.

The points of evaluation will be at $x_0 = 2$, $x_1 = 2 + h = 3$, and $x_2 = 2 + 2h = 4$.
Let $f(x) = x^2$. We need the function values at these points.
$y_0 = f(x_0) = f(2) = 2^2 = 4.$
$y_1 = f(x_1) = f(3) = 3^2 = 9.$
$y_2 = f(x_2) = f(4) = 4^2 = 16.$

The composite trapezoidal rule formula for n segments is:
$\int_a^b f(x)dx \approx \frac{h}{2}[y_0 + 2y_1 + ... + 2y_{n-1} + y_n].$
For $n = 2$, this becomes:

$\int_2^4 x^2 dx \approx \frac{h}{2}[y_0 + 2y_1 + y_2]$.

Substituting the values:
$\approx \frac{1}{2}[4 + 2(9) + 16] = \frac{1}{2}[4 + 18 + 16] = \frac{1}{2}[38] = 19.0$.

Quick Tip

The composite trapezoidal rule is $I \approx \frac{h}{2}[y_0 + y_n + 2\sum_{i=1}^{n-1} y_i]$. For $n = 2$, this simplifies to $I \approx \frac{h}{2}[y_0 + 2y_1 + y_2]$. Always carefully write down the node points and their function values before plugging into the formula.

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120. Let $f(x) = x^3 + 2x^2 + 3x - 1$. Newton-Raphson method is used to find the root of the equation f(x)=0. If the initial guess is $x_0 = 1$, then the value of x after first iteration is
(A) 0.30
(B) 0.36
(C) 0.40
(D) 0.50

Correct Answer: (D) 0.50

Solution:
The Newton-Raphson method formula for the next approximation (x_{n+1}) from the current approximation (x_n) is:
$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$

We are given the function $f(x) = x^3 + 2x^2 + 3x - 1$.
First, we need to find its derivative, $f'(x)$.
$f'(x) = 3x^2 + 4x + 3$.

The initial guess is given as $x_0 = 1$. We need to find the value after the first iteration, which is x_1.
$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$

Now, evaluate $f(x_0)$ and $f'(x_0)$ at $x_0 = 1$.
$f(1) = (1)^3 + 2(1)^2 + 3(1) - 1 = 1 + 2 + 3 - 1 = 5$.
$f'(1) = 3(1)^2 + 4(1) + 3 = 3 + 4 + 3 = 10$.

Substitute these values back into the formula for x_1:
$x_1 = 1 - \frac{5}{10}$
$x_1 = 1 - 0.5$

$x_1 = 0.50$.

Quick Tip

The Newton-Raphson method involves these steps: 1. Define $f(x)$. 2. Find the derivative $f'(x)$. 3. Start with an initial guess x_0. 4. Apply the iterative formula: $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$. Be careful with the signs and calculations.
