General Aptitude

Q.1 – Q.5 Carry ONE mark Each

Q.1	Fish : Shoal :: Lion : _____ Select the correct option to complete the analogy.
(A)	Pride
(B)	School
(C)	Forest
(D)	Series

Q.2	Identify the grammatically correct sentence:
(A)	It is I who am responsible for this fiasco.
(B)	It is myself who is responsible for this fiasco.
(C)	It is I who is responsible for this fiasco.
(D)	It is I who are responsible for this fiasco.

Q.3	Two cars, P and Q, start from a point X in India at 10 AM. Car P travels North with a speed of 25 km/h and car Q travels East with a speed of 30 km/h. Car P travels continuously but car Q stops for some time after travelling for one hour. If both the cars are at the same distance from X at 11:30 AM, for how long (in minutes) did car Q stop?
(A)	10
(B)	12
(C)	15
(D)	18

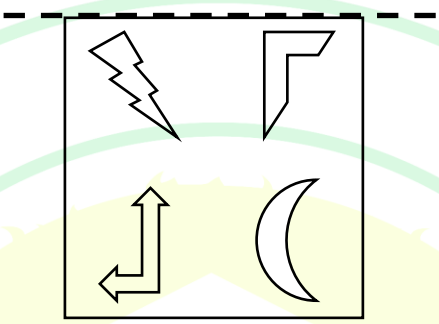
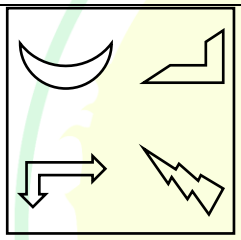
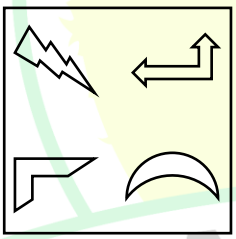
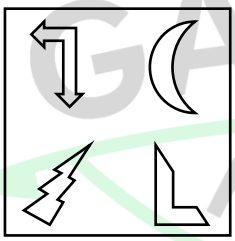
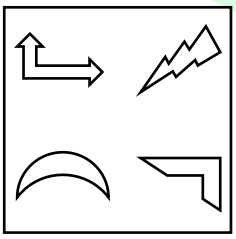
Q.4	The ceiling function of a real number x, denoted by $ce(x)$, is defined as the smallest integer that is greater than or equal to x. Similarly, the floor function, denoted by $fl(x)$, is defined as the largest integer that is smaller than or equal to x. Which one of the following statements is NOT correct for all possible values of x?
(A)	$ce(x) \geq x$
(B)	$fl(x) \leq x$
(C)	$ce(x) \geq fl(x)$
(D)	$fl(x) < ce(x)$

Q.5	P and Q play chess frequently against each other. Of these matches, P has won 80% of the matches, drawn 15% of the matches and lost 5% of the matches. If they play 3 more matches, what is the probability of P winning exactly 2 of these 3 matches?
(A)	$\frac{48}{125}$
(B)	$\frac{16}{125}$
(C)	$\frac{16}{25}$
(D)	$\frac{25}{48}$

Q.6 – Q.10 Carry TWO marks Each

Q.6	Identify the option that has the most appropriate sequence such that a coherent paragraph is formed: P. At once, without thinking much, people rushed towards the city in hordes with the sole aim of grabbing as much gold as they could. Q. However, little did they realize about the impending hardships they would have to face on their way to the city: miles of mud, unfriendly forests, hungry beasts and inimical local lords – all of which would reduce their chances of getting gold to almost zero. R. All of them thought that easily they could lay their hands on gold and become wealthy overnight. S. About a hundred years ago, the news that gold had been discovered in Kolar spread like wildfire and the whole State was in raptures.
(A)	P → Q → R → S
(B)	Q → S → R → P
(C)	S → Q → P → R
(D)	S → P → R → Q

Q.7	If HIDE and CAGE are coded as 19-23-7-11 and 5-2-17-11 respectively, then what is the code for HIGH?
(A)	5-17-1-2
(B)	17-19-13-17
(C)	13-3-1-2
(D)	19-23-17-19

Q.8	The given figure is reflected about the horizontal dashed line and then rotated clockwise by 90° about an axis perpendicular to the plane of the figure. Which one of the following options correctly shows the resultant figure? Note: The figures shown are representative.
	
(A)	
(B)	
(C)	
(D)	

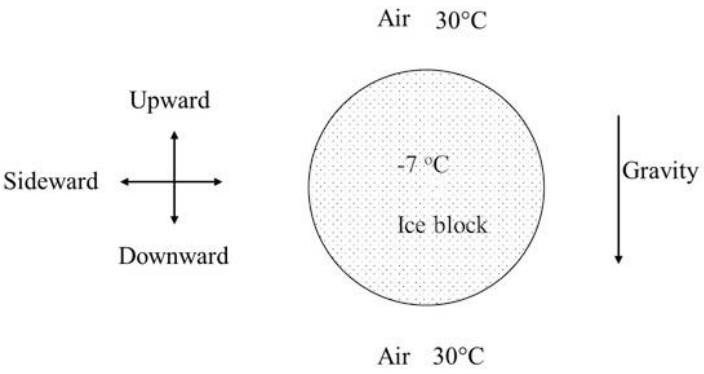
Q.9	Which one of the following options has the correct sequence of objects arranged in the increasing number of mirror lines (lines of symmetry)?
(A)	Circle; Square; Equilateral triangle; Isosceles triangle
(B)	Isosceles triangle; Equilateral triangle; Square; Circle
(C)	Equilateral triangle; Isosceles triangle; Square; Circle
(D)	Isosceles triangle; Square; Equilateral triangle; Circle

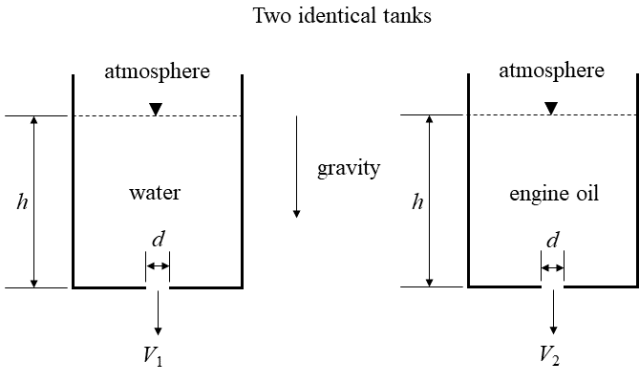
Q.10	A final year student appears for placement interview in two companies, S and T. Based on her interview performance, she estimates the probability of receiving job offers from companies S and T to be 0.8 and 0.6, respectively. Let p be the probability that she receives job offers from both the companies. Select the most appropriate option.
(A)	$0 \leq p \leq 0.2$
(B)	$0.4 \leq p \leq 0.6$
(C)	$0.2 \leq p \leq 0.4$
(D)	$0.6 \leq p \leq 1.0$

Q.11 – Q.35 Carry ONE mark Each

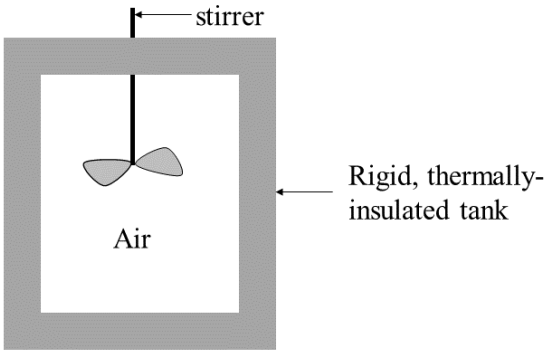
Q.11	Let **A** and **B** be real symmetric matrices of same size. Which one of the following options is correct?
(A)	$\mathbf{A}^T = \mathbf{A}^{-1}$
(B)	$\mathbf{AB} = \mathbf{BA}$
(C)	$(\mathbf{AB})^T = \mathbf{B}^T\mathbf{A}^T$
(D)	$\mathbf{A} = \mathbf{A}^{-1}$
Q.12	For the differential equation given below, which one of the following options is correct?
	$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0 \qquad 0 \le x \le 1, 0 \le y \le 1$
(A)	$u = e^{x+y}$ is a solution for all x and y
(B)	$u = e^x \sin y$ is a solution for all x and y
(C)	$u = \sin x \sin y$ is a solution for all x and y
(D)	$u = \cos x \cos y$ is a solution for all x and y

Q.13	The divergence of the curl of a vector field is
(A)	the magnitude of this vector field
(B)	the argument of this vector field
(C)	the magnitude of the curl of this vector field
(D)	zero
Q.14	If two unbiased coins are tossed, then what is the probability of having at least one head?
(A)	0.25
(B)	0.5
(C)	0.675
(D)	0.75

Q.15	Let a spherical block of ice at –7 °C be exposed to atmospheric air at 30 °C with the gravitational direction as shown in the figure below. What will be the overall direction of air flow in this situation?
	
(A)	Upward
(B)	Downward
(C)	NO motion
(D)	Sideward

Q. 16	Consider two identical tanks with a bottom hole of diameter *d*. One tank is filled with water and the other tank is filled with engine oil. The height of the fluid column *h* is same in both the cases. The fluid exit velocity in the two tanks are V_1 and V_2. Neglecting all losses, which one of the following options is correct?
	
(A)	$V_2 > V_1$
(B)	$V_2 = V_1$
(C)	$V_2 < V_1$
(D)	Insufficient data to definitively conclude the relationship between V_1 and V_2

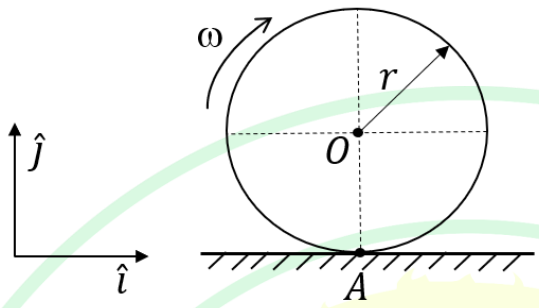
Q. 17	In a laboratory experiment using a scaled down model to measure scour at a bridge pier, the Froude number is important. The ratio of the prototype length to the model length is 100. If the velocity of the model is 1 m s^{-1}, the velocity (in m s^{-1}) of the prototype is
(A)	0.1
(B)	1
(C)	10
(D)	100

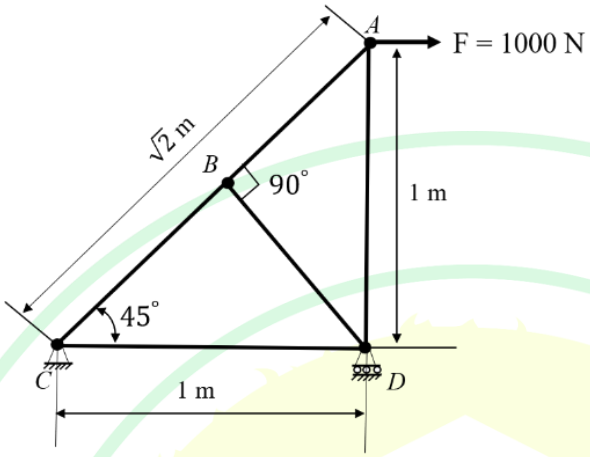
Q.18	Air inside a rigid, thermally-insulated tank undergoes stirring as shown in the figure below. Which one of the following options is correct?
	
(A)	The enthalpy of the air increases while the entropy of the air remains constant
(B)	Both the enthalpy and the entropy of the air remain constant
(C)	Both the enthalpy and the entropy of the air increase
(D)	The enthalpy of the air decreases while the entropy of the air increases
Q.19	In a psychrometric chart, one axis represents dry-bulb temperature. The axis, that is perpendicular to the dry-bulb temperature axis, represents
(A)	wet-bulb temperature
(B)	specific humidity
(C)	relative humidity
(D)	enthalpy

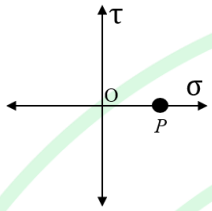
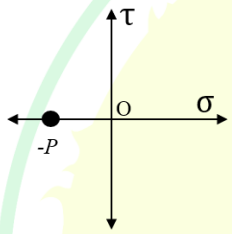
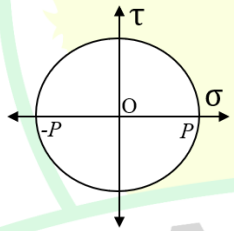
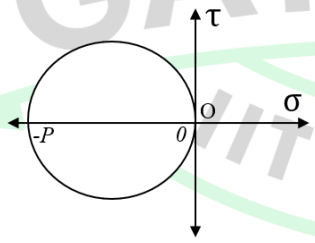
Q.20	Among the following surface hardening processes, steel is heated to the lowest temperature in
(A)	carburizing
(B)	cyaniding
(C)	nitriding
(D)	carbonitriding
Q.21	The welding process commonly used for fabricating tailor-welded blanks of dissimilar thickness for automotive applications is
(A)	gas welding
(B)	laser welding
(C)	arc welding
(D)	friction welding

Q.22	The yield stress of a metal in uniaxial tension is 200 MPa. According to von Mises yield criterion, the yield stress (in MPa) of the metal in pure shear is closest to
(A)	115.5
(B)	100.0
(C)	66.7
(D)	141.4
Q.23	In computer aided design (CAD), solid models can be constructed using
(A)	boundary representation (B-rep)
(B)	Bezier curves
(C)	B-splines
(D)	nonuniform rational B-splines (NURBS)

Q.24	Ceramics and glass are machined by
(A)	electric discharge machining
(B)	ultrasonic machining
(C)	electrochemical machining
(D)	transferred arc plasma machining
Q.25	When assembled, the hole $30^{+0.030}_{+0.000}$ mm and shaft $30^{+0.020}_{-0.020}$ mm will result in
(A)	loose fit
(B)	interference fit
(C)	transition fit
(D)	clearance fit

Q.26	A rigid circular disc of radius r (in m) is rolling without slipping on a flat surface as shown in the figure below. The angular velocity of the disc is ω (in rad s^{-1}). The velocities (in m s^{-1}) at points O and A, respectively, are
	
(A)	$r\omega\,\hat{\imath}$ and $0\,\hat{\imath}$
(B)	$-r\omega\,\hat{\imath}$ and $0\,\hat{\imath}$
(C)	$-r\omega\,\hat{\imath}$ and $-r\omega\,\hat{\imath}$
(D)	$r\omega\,\hat{\imath}$ and $r\omega\,\hat{\imath}$

Q.27	A truss structure is loaded as shown in the figure below. Among the options given, which member in the truss is a zero-force member?
	
(A)	*BD*
(B)	*BC*
(C)	*BA*
(D)	*AD*

Q.28	A metallic square plate is subjected to a uniform hydrostatic pressure (P). Choose the correct Mohr's circle representing the state of stress at any point in the plate from the options given below. *For the Mohr's circle, normal stress is positive towards right and shear stress is positive in the upward direction.*
(A)	
(B)	
(C)	
(D)	

Q.29	In the context of balancing of rotating and reciprocating masses, which one of the following options is true?
(A)	An unbalanced rigid rotor can be completely balanced using a single balancing mass
(B)	An unbalanced rigid rotor can be completely balanced using two balancing masses attached in two distinct planes
(C)	A single-cylinder internal combustion engine can be completely balanced using a single balancing mass
(D)	A single-cylinder internal combustion engine can be completely balanced using two balancing masses
Q.30	A shaft carries a helical spur gear. Which one of the following bearings can NOT be used to support it?
(A)	Angular contact bearing
(B)	Double-row ball bearing
(C)	Straight roller bearing
(D)	Tapered roller bearing

Q.31 The values of a function f obtained for different values of x are shown in the table below.

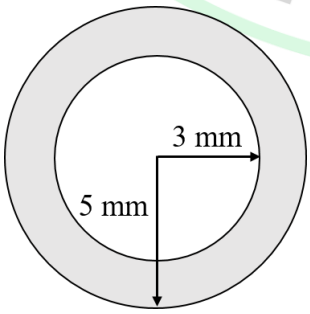
x	0	0.25	0.5	0.75	1.0
$f(x)$	0.9	2.0	1.5	1.8	0.4

Using Simpson's one-third rule,

$\int_0^1 f(x)\,dx \approx$ _____ (*rounded off to 2 decimal places*).

Q.32 The thermal efficiency of an ideal air-standard Otto cycle is 0.5. The value of specific heat ratio of air is 1.4. The compression ratio of the cycle is _____ (*rounded off to 1 decimal place*).

Q.33 During a welding operation, thermal power of 2500 W is incident normally on a metallic surface. As shown in the figure below (figure is NOT to scale), the heated area is circular. Out of the incident power, 85% of the power is absorbed within a circle of radius 5 mm while 65% is absorbed within an inner concentric circle of radius 3 mm. The power density in the shaded area is _____ W mm^{-2} (*rounded off to 2 decimal places*).



Q.34	A liquid metal is poured in a mold cavity of size 200 mm × 200 mm × 200 mm. The cooling is uniform in all directions with NO additional compensation for shrinkage. Considering the volumetric shrinkage during solidification and solid contraction as 7% and 8%, respectively, the length of the cube edge after cooling down to the room temperature is _____ mm (*rounded off to 1 decimal place*).
Q.35	A block of mass 1 kg connected to a spring of stiffness 10 N m^{-1} is operating in a viscous medium such that the damping ratio (or damping factor) is equal to the ratio of the damped frequency to the natural frequency. The magnitude of the damping ratio for this system is _____ (*rounded off to 2 decimal places*).

Q.36 – Q.65 Carry TWO marks Each

<table>
<tr><td>Q.36</td><td>In the closed interval $[0, 3]$, the minimum value of the function f given below is
$f(x) = 2x^3 - 9x^2 + 12x$</td></tr>
<tr><td>(A)</td><td>0</td></tr>
<tr><td>(B)</td><td>4</td></tr>
<tr><td>(C)</td><td>5</td></tr>
<tr><td>(D)</td><td>9</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Q.37</td><td>Considering the actual demand and the forecast for a product given in the table below, the mean forecast error and the mean absolute deviation, respectively, are
<table>
<tr><td>Period</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>Actual demand</td><td>425</td><td>415</td><td>420</td><td>430</td><td>427</td><td>418</td><td>422</td><td>416</td><td>426</td><td>421</td></tr>
<tr><td>Forecast</td><td>427</td><td>422</td><td>416</td><td>422</td><td>423</td><td>420</td><td>419</td><td>418</td><td>430</td><td>415</td></tr>
</table></td></tr>
<tr><td>(A)</td><td>0.8 and 42.0</td></tr>
<tr><td>(B)</td><td>0.8 and 4.2</td></tr>
<tr><td>(C)</td><td>8.0 and 42.0</td></tr>
<tr><td>(D)</td><td>8.0 and 4.2</td></tr>
</table>

Q.38 Match the mold elements in the casting process with the most suitable function

Mold element		Function	
P	Blind riser	I	Casting with internal cavity
Q	Chill	II	Molten metal reservoir
R	Skim bob	III	Nucleating agent
S	Core	IV	Assisting in faster heat removal from melt
T	Insulating sleeve	V	Removal of impurities
U	Inoculant	VI	Increasing the solidification time

(A) P-II, Q-IV, R-V, S-I, T-VI, U-III

(B) P-II, Q-V, R-VI, S-I, T-III, U-IV

(C) P-V, Q-I, R-VI, S-III, T-II, U-IV

(D) P-II, Q-IV, R-I, S-V, T-VI, U-III

Q.39	Wire drawing operation is performed on a perfectly plastic metal without any strain hardening. Assuming no friction and no redundant work, the maximum possible percentage reduction in area in a single pass is closest to
(A)	51.2
(B)	63.2
(C)	75.0
(D)	93.2

Q.40 In relation to additive manufacturing, match the following

Process		Layer creation technique		Material	
P	Stereolithography	1	Injection of powder stream	I	Paper
Q	Fused deposition modeling	2	Extrusion of melted polymer	II	Epoxy
R	Laminated object manufacturing	3	Liquid layer curing	III	Titanium
S	Laser-engineered net shaping	4	Sheet material deposition	IV	Acrylonitrile butadiene styrene (ABS)

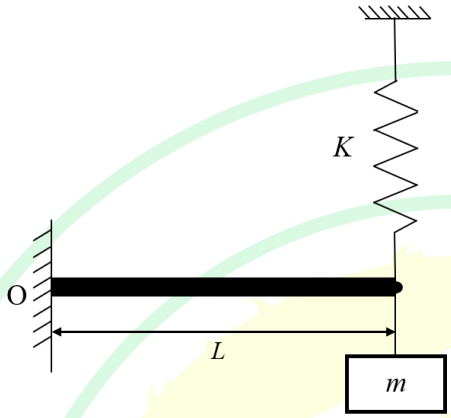
(A) P-3-III, Q-1-IV, R-4-I, S-2-II

(B) P-3-II, Q-2-IV, R-4-I, S-1-III

(C) P-4-III, Q-2-IV, R-1-II, S-3-I

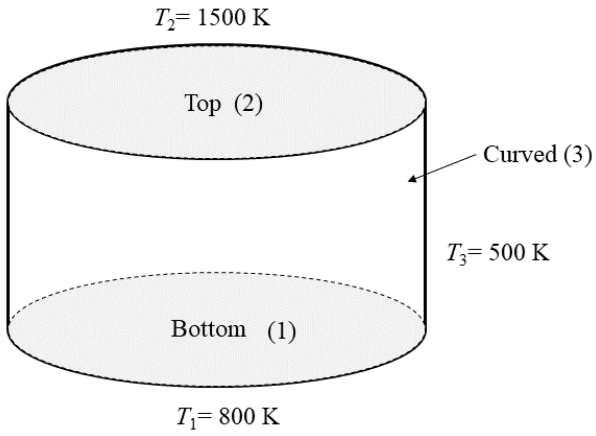
(D) P-3-II, Q-2-IV, R-1-I, S-4-III

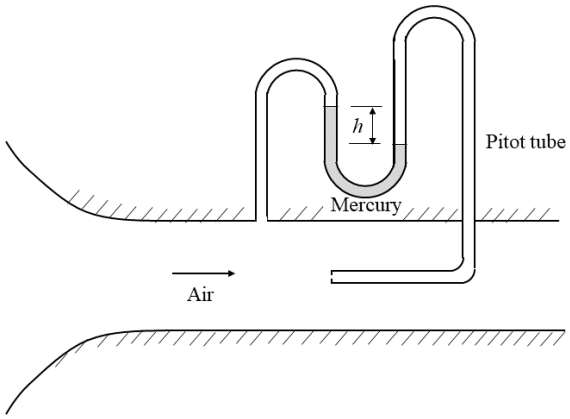
Q.41	A plate of 30 mm thickness is fed through a rolling mill with two powered rolls. Each roll has a diameter of 500 mm. The plate thickness is to be reduced to 27 mm in a single pass. Assume no change in width. The process feasibility and the maximum draft (in mm) can be represented, respectively, as Use the coefficient of friction as 0.12
(A)	feasible and 3.6
(B)	NOT feasible and 2.6
(C)	feasible and 3.0
(D)	NOT feasible and 6.0

Q.42	The system shown in the figure below consists of a cantilever beam (with flexural rigidity EI and negligible mass), a spring (with spring constant K and negligible mass) and a block of mass m. Assuming a lumped parameter model for the system, the fundamental natural frequency (ω_n) of the system is
	
(A)	$\sqrt{\frac{\frac{3EI}{L^3}+K}{m}}$
(B)	$\sqrt{\frac{\frac{EI}{L^3}+K}{m}}$
(C)	$\sqrt{\frac{\frac{3EI}{L^3}+K}{2m}}$
(D)	$\sqrt{\frac{\frac{EI}{L^3}+K}{2m}}$

Q.43	The endurance limit of a specific grade of steel is same as its yield strength. The ultimate strength of this grade of steel is twice of its yield strength. A component made of this steel is loaded in tension and unloaded periodically. It is required that the component does NOT fail for at least 10^6 loading cycles, as per the Soderberg law. Considering a factor of safety of 2, the maximum applied tensile principal stress is
(A)	one-fourth of the endurance limit
(B)	half of the endurance limit
(C)	the endurance limit
(D)	twice the endurance limit
Q.44	For a fully-developed pipe flow, which of the following options is/are correct?
(A)	For the same maximum velocity, the average velocity is higher in the turbulent regime than that of the laminar regime
(B)	Compressibility effects are important if Mach number is less than 0.3
(C)	For laminar flow, the friction factor is independent of surface roughness
(D)	For laminar flow, friction factor decreases with decrease in Reynolds number

Q.45	If C is the unit circle in the complex plane with its center at the origin, then the value of n in the equation given below is _____ (*rounded off to 1 decimal place*).
	$$\oint_C \frac{z^3}{(z^2+4)\,(z^2-4)}\,dz = 2\,\pi\,i\,n$$
Q.46	The directional derivative of the function f given below at the point $(1, 0)$ in the direction of $\frac{1}{2}\left(\hat{\imath} + \sqrt{3}\,\hat{\jmath}\right)$ is _____ (*rounded off to 1 decimal place*).
	$$f(x, y) = x^2 + xy^2$$
Q.47	Let y be the solution of the differential equation with the initial conditions given below. If $y(x = 2) = A \ln 2$, then the value of A is _____ (*rounded off to 2 decimal places*).
	$$x^2\frac{d^2y}{dx^2} + 3x\frac{dy}{dx} + y = 0 \qquad y(x = 1) = 0 \qquad \frac{dy}{dx}(x = 1) = 1$$

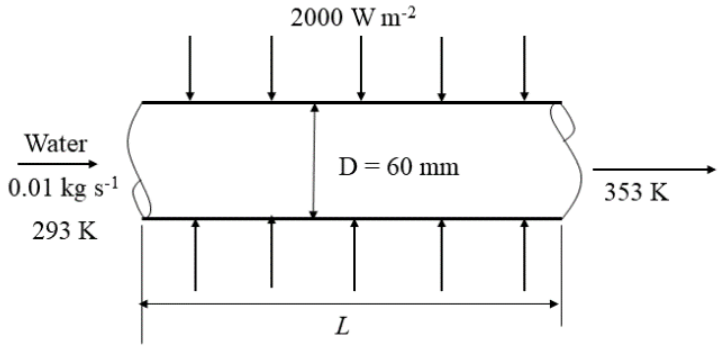
Q.48	Consider a cylindrical furnace of 5 m diameter and 5 m length with bottom, top and curved surfaces maintained at uniform temperatures of 800 K, 1500 K and 500 K, respectively. The view factor between the bottom and top surfaces, F_{12} is 0.2. The magnitude of net radiation heat transfer rate between the bottom surface and the curved surface is _____ kW (*rounded off to 1 decimal place*). All surfaces of the furnace can be assumed as black. The Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}.
	

Q.49	A pitot tube connected to a U-tube mercury manometer measures the speed of air flowing in the wind tunnel as shown in the figure below. The density of air is 1.23 kg m^{-3} while the density of water is 1000 kg m^{-3}. For the manometer reading of $h =$ 30 mm of mercury, the speed of air in the wind tunnel is _____ m s^{-1} (*rounded off to 1 decimal place*). Assume: Specific gravity of mercury =13.6 Acceleration due to gravity = 10 m s^{-2}
	
Q. 50	Consider a velocity field $\vec{V} = 3z\,\hat{\imath} + 0\,\hat{\jmath} + Cx\,\hat{k}$, where C is a constant. If the flow is irrotational, the value of C is _____ (*rounded off to 1 decimal place*).

Q. 51

Water enters a tube of diameter, D = 60 mm with mass flow rate of 0.01 kg s^{-1} as shown in the figure below. The inlet mean temperature is $T_{m,i}$ = 293 K and the uniform heat flux at the surface of the tube is 2000 W m^{-2}. For the exit mean temperature of $T_{m,o}$ = 353 K, the length of the tube, *L* is _____m (*rounded off to 1 decimal place*).

Use the specific heat of water as 4181 J kg^{-1} K^{-1}.

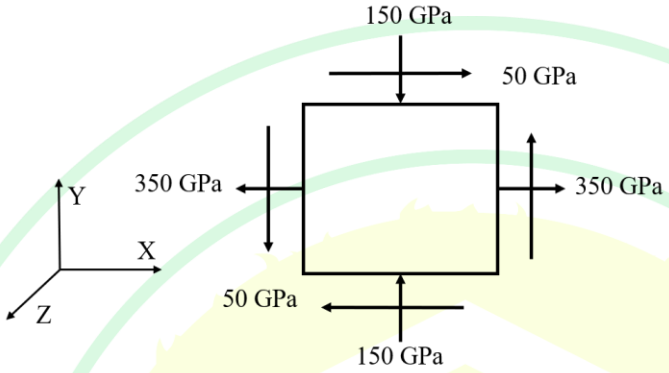
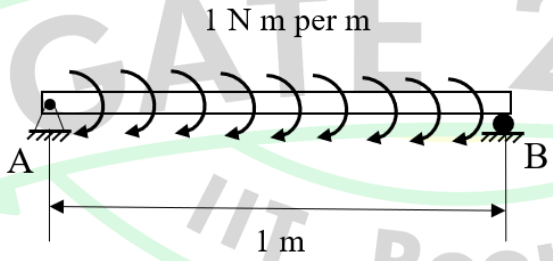


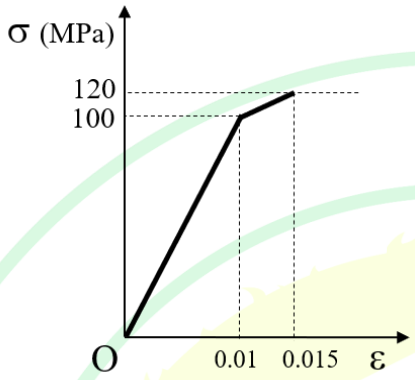
Q. 52

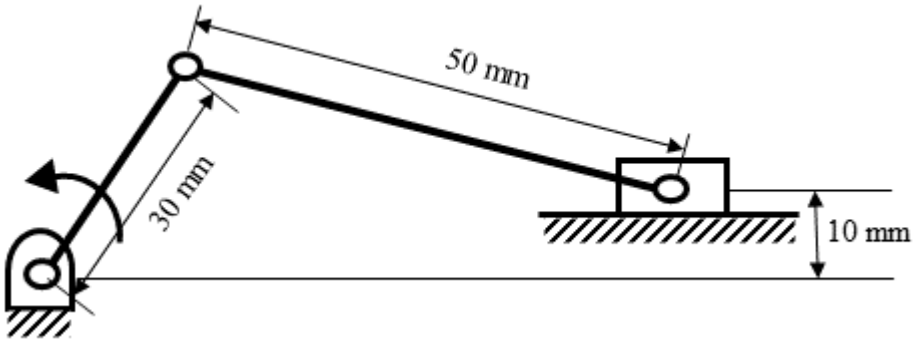
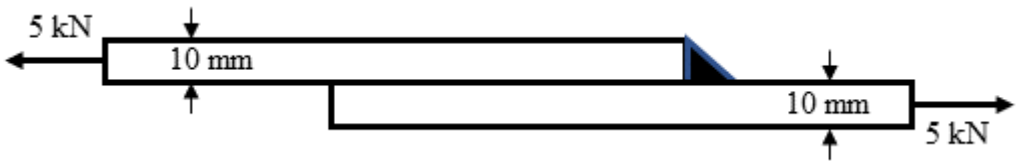
A thermal power plant is running with no reheat or regeneration. The specific enthalpy and specific entropy of steam at the turbine inlet are 3344 kJ kg^{-1} and 6.5 kJ kg^{-1} K^{-1}, respectively. The turbine isentropic efficiency is 0.9, and the mass flow rate of steam at the turbine inlet is 102 kg s^{-1}. The turbine power output is _____ MW (*rounded off to 1 decimal place*).

Properties of saturated liquid and saturated vapor at turbine exit pressure			
Saturated liquid water		Saturated water vapor	
Specific enthalpy (kJ kg^{-1})	Specific entropy (kJ kg^{-1} K^{-1})	Specific enthalpy (kJ kg^{-1})	Specific entropy (kJ kg^{-1} K^{-1})
341	1.1	2645	7.6

Q. 53	Consider a Pelton wheel of 1 m diameter. The magnitude of relative velocity of water at the bucket inlet is same as the magnitude of relative velocity of water at the bucket exit. The absolute speed of water at the bucket inlet is 125.66 m s^{-1}. For maximum power output from the Pelton wheel, the rpm of the Pelton wheel is _____ (*rounded off to 1 decimal place*).
Q. 54	A thermodynamically closed system contains 1 kg of hydrogen. The system undergoes a reversible polytropic process with polytropic index 1.3. The work output during the process is 400 kJ. During the process, hydrogen behaves as an ideal gas with constant specific heats. The absolute value of heat transfer during the process is _____ kJ (*rounded off to 1 decimal place*). Specific heat of hydrogen at constant pressure = 14.56 kJ kg^{-1} K^{-1} Specific heat of hydrogen at constant volume = 10.4 kJ kg^{-1} K^{-1}
Q. 55	A heat pump, operating in reversed Carnot cycle, maintains a steady air temperature of 300 K inside an auditorium. The heat pump receives heat from the ambient air. The ambient air temperature is 280 K. Heat loss from the auditorium is 15 kW. The power consumption of the heat pump is ____ kW (*rounded off to 2 decimal places*).

Q.56	The state of stress at a point is shown in the figure given below. Under plane stress assumption, the normal strain along the thickness direction (ε_{zz}) is _____ (*rounded off to 2 decimal places*). Use the Young's Modulus E = 200 GPa and Poisson's ratio ν = 0.27.
	
Q.57	A simply supported beam of length 1 m is subjected to a uniformly distributed bending moment of 1 N m per m throughout the length as shown in the figure given below. The bending moment at the mid-point of the beam is_____N m (*rounded off to the nearest integer*).
	

Q.58	An isotropic brittle material is tested in the universal testing machine. The stress-strain diagram for the material shows a bi-linear elastic behavior as shown in the figure given below. The strain energy density is _____ MJ m^{-3} (*rounded off to 2 decimal places*).
	
Q.59	A pair of spur gears is required to maintain a velocity ratio of 1:2. The module of the gears is 10 mm and the addendum is 10 mm. If the operating pressure angle is 15°, the minimum number of teeth required on the pinion to ensure NO interference/undercutting is ____ (*answer in integer*).

Q.60	An offset slider-crank mechanism is shown in the figure below. The length of the stroke of the slider is _____ mm (*rounded off to nearest integer*).
	
Q.61	Two plates of thickness 10 mm each are to be joined by a transverse fillet weld on one side and the resulting structure is loaded as shown in the figure below. If the ultimate tensile strength of the weld material is 150 MPa and the factor of safety to be used is 3, the minimum length of the weld required to ensure that the weld does NOT fail is _____ mm (*rounded off to 2 decimal places*).
	

Q.62	Two metal parts (a cylinder and a cube) of same volume are cast under identical conditions. The diameter of the cylinder is equal to its height. The ratio of the solidification time of the cube to that of the cylinder is_____ (*rounded off to 2 decimal places*). Assume that solidification time follows Chvorinov's rule with an exponent of 2.
Q.63	Cylindrical workpieces of diameter 60 mm and length 400 mm are machined on a lathe at a cutting speed of 25 m min^{-1} and a feed of 0.2 mm rev^{-1}. The Taylor's tool life parameters C and n for this setup are 75 and 0.25, respectively. The tool changing time is 3 minutes. With a labor and overhead cost of ₹ 5 per minute, the tool changing cost per piece is ₹ _____ (*rounded off to 2 decimal places*).
Q.64	A company uses 3000 units of a part annually. The units are priced as given in the table below. It costs ₹ 150 to place an order. Carrying costs are 40 percent of the purchase price per unit on an annual basis. The minimum total annual cost is ₹ _____ (*rounded off to 1 decimal place*).

Order quantity	Unit price (₹)
1 to 499	9.0
500 to 999	8.5
1000 or more	8.0

Q.65 A project involves eight activities with the precedence relationship and duration as shown in the table below. The slack for the activity D is _____ hours (*answer in integer*).

Activity	Immediate predecessor	Duration (hours)
A	-	4
B	A	8
C	A	5
D	B	2
E	B	7
F	C	6
G	D	3
H	E, F, G	9

GATE 2025 Mechanical Engineering Question Paper with Solutions

Time Allowed :180 Minutes	**Maximum Marks :**100	**Total questions :**65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. **Total Marks:** The GATE Mechanical Engineering paper is worth 100 marks.
2. **Question Types:** The paper consists of 65 questions, divided into:
   - General Aptitude (GA): 15 marks
   - Engineering Mathematics and Core Mechanical Engineering: 85 marks
3. **Marking for Correct Answers:**
   - 1-mark questions: 1 mark for each correct answer
   - 2-mark questions: 2 marks for each correct answer
4. **Negative Marking for Incorrect Answers:**
   - 1-mark MCQs: 1/3 mark deduction for a wrong answer
   - 2-mark MCQs: 2/3 marks deduction for a wrong answer
5. **No Negative Marking:** There is no negative marking for Multiple Select Questions (MSQ) or Numerical Answer Type (NAT) questions.
6. **No Partial Marking:** There is no partial marking in MSQ.

General Aptitude

1. Fish : Shoal :: Lion : _____

Select the correct option to complete the analogy.

(A) Pride

(B) School

(C) Forest

(D) Series

Correct Answer: (A) Pride

Solution: To solve this analogy, we need to recognize the relationship between the words ”Fish” and ”Shoal.” A ”shoal” is a term used to describe a group of fish. Now, we need to find the term that describes a group of lions.

- The term for a group of lions is a ”pride.”
- The terms ”School,” ”Forest,” and ”Series” do not refer to groups of lions.

Thus, the correct analogy is: **Fish : Shoal** is analogous to **Lion : Pride**. Therefore, the correct answer is (A) Pride.

Quick Tip

When solving analogy questions, focus on understanding the relationship between the given terms. Look for the group or collective noun for animals, objects, or people in the analogy.

---

2. Identify the grammatically correct sentence:

(A) It is I who am responsible for this fiasco.

(B) It is myself who is responsible for this fiasco.

(C) It is I who is responsible for this fiasco.

(D) It is I who are responsible for this fiasco.

Correct Answer: (A) It is I who am responsible for this fiasco.

Solution: In this sentence, ”It is I” is the subject, and ”am” is the correct verb for ”I.” This is

a formal construction, and the verb ”am” correctly agrees with the subject ”I.” The other options contain errors in subject-verb agreement or incorrect pronoun usage.

- **Option (A): ”It is I who am responsible for this fiasco.”** This is grammatically correct because the subject ”I” requires the verb ”am.”
- **Option (B): ”It is myself who is responsible for this fiasco.”** The reflexive pronoun ”myself” is incorrect. It should be ”I” instead.
- **Option (C): ”It is I who is responsible for this fiasco.”** This sentence is incorrect because the subject ”I” requires ”am” and not ”is.”
- **Option (D): ”It is I who are responsible for this fiasco.”** This is incorrect because ”are” is plural, and ”I” is singular.

Quick Tip

In sentences starting with ”It is I,” the verb after ”I” must be in the singular form, not plural. Always ensure subject-verb agreement in complex sentences.

---

3. Two cars, P and Q, start from a point X in India at 10 AM. Car P travels North with a speed of 25 km/h and car Q travels East with a speed of 30 km/h. Car P travels continuously but car Q stops for some time after traveling for one hour. If both cars are at the same distance from X at 11:30 AM, for how long (in minutes) did car Q stop?

(A) 10

(B) 12

(C) 15

(D) 18

Correct Answer: (C) 15 **Solution:**

Step 1: Analyze the positions of cars at 11:00 AM. Car P travels at 25 km/h for 1.5 hours (from 10 AM to 11:30 AM), so the distance traveled by car P is:

$$\text{Distance of car P} = 25 \times 1.5 = 37.5 \text{ km}.$$

Car Q travels at 30 km/h for 1 hour, so the distance covered by car Q in the first hour is:

$$\text{Distance of car Q in 1 hour} = 30 \times 1 = 30 \text{ km}.$$

Step 2: Use the Pythagorean theorem.

Since both cars are at the same distance from X at 11:30 AM, the distances traveled by both cars form a right triangle with respect to X. For car Q to meet car P at the same distance, we calculate the missing distance using the Pythagorean theorem:

$$\text{Distance of car Q at 11:30 AM} = \sqrt{(30^2 + 37.5^2)} \approx 47.43 \text{ km}.$$

Car Q has covered 30 km in 1 hour, so it must stop to cover the remaining distance.

Step 3: Calculate the time Q stopped.

Car Q needs to travel $47.43 - 30 = 17.43$ km. At a speed of 30 km/h, the time taken to travel this distance is:

$$\text{Time taken to travel remaining distance} = \frac{17.43}{30} \times 60 = 34.86 \text{ minutes}.$$

Thus, car Q must have stopped for approximately $34.86 - 15 = 15$ minutes.

Quick Tip

When dealing with relative motion and distances, use the Pythagorean theorem to find the exact distance when two objects move at right angles.

---

4. The ceiling function of a real number x, denoted by $ce(x)$, is defined as the smallest integer that is greater than or equal to x. Similarly, the floor function, denoted by $fl(x)$, is defined as the largest integer that is smaller than or equal to x. Which one of the following statements is NOT correct for all possible values of x?

(A) $ce(x) \geq x$

(B) $fl(x) \leq x$

(C) $ce(x) \geq fl(x)$

(D) $fl(x) < ce(x)$

Correct Answer: (D)

Solution:

The ceiling function $ce(x)$ returns the smallest integer greater than or equal to x.

The floor function $fl(x)$ returns the largest integer smaller than or equal to x.

Now, we analyze each option:

Option (A): $ce(x) \geq x$.

This is true since the ceiling of x is the smallest integer greater than or equal to x.

Option (B): $fl(x) \leq x$.

This is true since the floor of x is the largest integer smaller than or equal to x.

Option (C): $ce(x) \geq fl(x)$.

This is true because the ceiling of x is always greater than or equal to the floor of x.

Option (D): $fl(x) < ce(x)$.

This is NOT true for all x. For example, if x is an integer, then $fl(x) = ce(x) = x$, so $fl(x)$ is not strictly less than $ce(x)$.

Thus, the correct answer is option (D).

Quick Tip

Remember that the ceiling function always rounds up, while the floor function always rounds down. So, for non-integer values, $fl(x)$ will always be less than $ce(x)$.

---

5. P and Q play chess frequently against each other. Of these matches, P has won 80% of the matches, drawn 15% of the matches, and lost 5% of the matches.

If they play 3 more matches, what is the probability of P winning exactly 2 of these 3 matches?

(A) $\frac{48}{125}$

(B) $\frac{16}{125}$

(C) $\frac{16}{25}$

(D) $\frac{25}{48}$

Correct Answer: (A) $\frac{48}{125}$

Solution: Let's define the possible outcomes of a match. From the given data:

The probability of P winning a match is $P(\text{Win}) = 0.80$.

The probability of P drawing a match is $P(\text{Draw}) = 0.15$.

The probability of P losing a match is $P(\text{Loss}) = 0.05$.

We are asked to find the probability of P winning exactly 2 out of the 3 matches. Since the outcome of each match is independent, this is a binomial probability problem, where we need to calculate the probability of 2 wins out of 3 trials.

The binomial probability formula is:

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

where:

$n = 3$ (number of matches),

$k = 2$ (number of wins),

$p = 0.80$ (probability of winning),

$1 - p = 0.20$ (probability of not winning).

The probability of exactly 2 wins is:

$$P(X = 2) = \binom{3}{2} (0.80)^2 (0.20)^1 = 3 \times 0.64 \times 0.20 = \frac{48}{125}.$$

Thus, the correct answer is $\frac{48}{125}$.

Quick Tip

When solving binomial probability problems, remember the formula $P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$ and carefully calculate the combinations, probabilities, and powers.

---

6. Identify the option that has the most appropriate sequence such that a coherent paragraph is formed:

P. At once, without thinking much, people rushed towards the city in hordes with the sole aim of grabbing as much gold as they could.

Q. However, little did they realize about the impending hardships they would have to face on their way to the city: miles of mud, unfriendly forests, hungry beasts, and inimical local lords—all of which would reduce their chances of getting gold to almost zero.

R. All of them thought that easily they could lay their hands on gold and become wealthy overnight.

S. About a hundred years ago, the news that gold had been discovered in Kolar spread like wildfire and the whole State was in raptures.

(A) P $\rightarrow$ Q $\rightarrow$ R $\rightarrow$ S

(B) Q $\rightarrow$ S $\rightarrow$ R $\rightarrow$ P

(C) S $\rightarrow$ Q $\rightarrow$ P $\rightarrow$ R

(D) S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q

Correct Answer: (D) S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q

Solution: The correct sequence of sentences to form a coherent paragraph is: S: ”About a hundred years ago, the news that gold had been discovered in Kolar spread like wildfire and the whole State was in raptures.” This sentence introduces the context of the gold discovery, setting up the paragraph.

P: ”At once, without thinking much, people rushed towards the city in hordes with the sole aim of grabbing as much gold as they could.” This sentence follows, describing the reaction of the people upon hearing the news.

R: ”All of them thought that easily they could lay their hands on gold and become wealthy overnight.” This continues the description of the people’s naive thinking about the gold rush.

Q: ”However, little did they realize about the impending hardships they would have to face on their way to the city: miles of mud, unfriendly forests, hungry beasts, and inimical local lords—all of which would reduce their chances of getting gold to almost zero.” This final sentence adds a twist by describing the hardships the people would face, bringing the paragraph to a conclusion.

Thus, the correct sequence is S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q.

Quick Tip

When solving paragraph sequencing problems, focus on finding sentences that logically flow from one to another. Look for the sentence that introduces the context first, followed by actions, then consequences, and finally a concluding or reflective statement.

---

7. If HIDE and CAGE are coded as 19-23-7-11 and 5-2-17-11 respectively, then what is the code for HIGH?

(A) 5-17-1-2

(B) 17-19-13-17

(C) 13-3-1-2

(D) 19-23-17-19

Correct Answer: (D) 19-23-17-19

Solution: We are given the following codes:

- HIDE is coded as 19-23-7-11

- CAGE is coded as 5-2-17-11

Let's break down the pattern:

1. For HIDE:

- H = 19

- I = 23

- D = 7

- E = 11

2. For CAGE:

- C = 5

- A = 2

- G = 17

- E = 11

Now, let's find the code for HIGH:

- H corresponds to 19 (from HIDE).

- I corresponds to 23 (from HIDE).

- G corresponds to 17 (from CAGE).

- H corresponds to 19 (from HIDE).

Thus, the code for HIGH is 19-23-17-19.

Therefore, the correct answer is (D) 19-23-17-19.

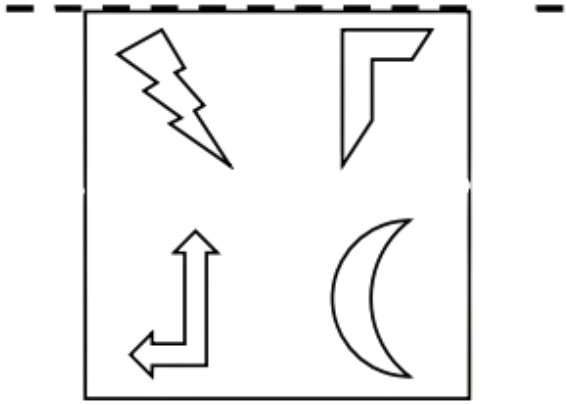
Quick Tip

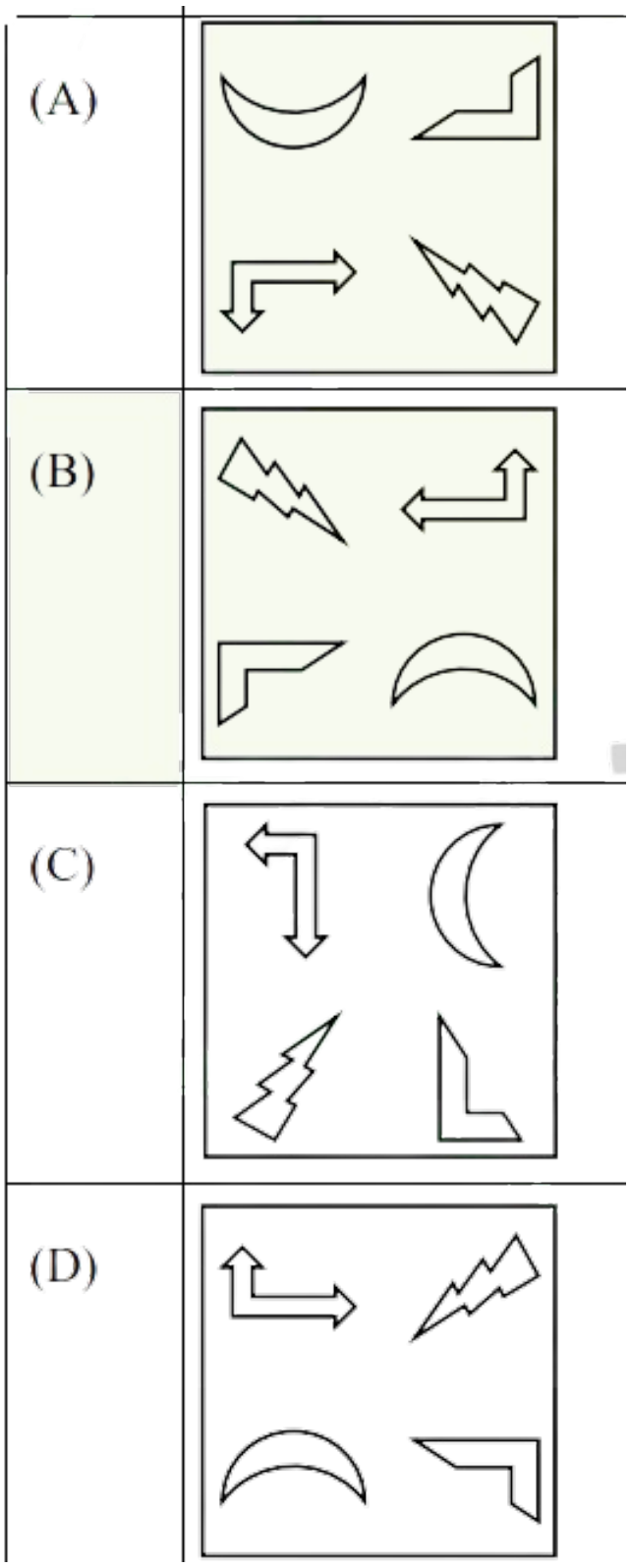
When solving letter-to-number coding problems, check the pattern of letters and their corresponding numbers carefully. The pattern might be consistent across different words.

8. The given figure is reflected about the horizontal dashed line and then rotated clockwise by 90° about an axis perpendicular to the plane of the figure.

Which one of the following options correctly shows the resultant figure?

Note: The figures shown are representative





Correct Answer: (B)

Solution: Step 1: **Reflection**

The first step is reflecting the figure about the horizontal dashed line. This will invert the figure along the axis of reflection. The lightning bolt shape and the curved shapes will be

mirrored.

Step 2: **Rotation**

Next, the figure is rotated clockwise by 90° about an axis perpendicular to the plane of the figure. This means that the shapes will be rotated, each shape moving 90° in the clockwise direction.

By applying these transformations, we observe that the correct option, which matches the described transformation, is **(B)**.

Thus, the correct answer is **(B)**.

Quick Tip

When dealing with reflection and rotation problems, visualize the transformations step by step. Begin with the reflection, then apply the rotation to each shape, carefully considering their new orientation.

---

9. Which one of the following options has the correct sequence of objects arranged in the increasing number of mirror lines (lines of symmetry)?

(A) Circle; Square; Equilateral triangle; Isosceles triangle

(B) Isosceles triangle; Equilateral triangle; Square; Circle

(C) Equilateral triangle; Isosceles triangle; Square; Circle

(D) Isosceles triangle; Square; Equilateral triangle; Circle

Correct Answer: (B) Isosceles triangle; Equilateral triangle; Square; Circle

Solution: An isosceles triangle has 1 line of symmetry (a vertical line passing through the vertex opposite the base).

An equilateral triangle has 3 lines of symmetry (vertical axis passing through each vertex).

A square has 4 lines of symmetry (horizontal, vertical, and two diagonals).

A circle has infinite lines of symmetry (can be divided into equal parts in many ways).

Quick Tip

For symmetry questions, focus on the geometric properties of each figure, such as the number of equal parts or axes of symmetry.

10. A final year student appears for placement interview in two companies, S and T. Based on her interview performance, she estimates the probability of receiving job offers from companies S and T to be 0.8 and 0.6, respectively. Let p be the probability that she receives job offers from both the companies. Select the most appropriate option.

(A) $0 \leq p \leq 0.2$

(B) $0.4 \leq p \leq 0.6$

(C) $0.2 \leq p \leq 0.4$

(D) $0.6 \leq p \leq 1.0$

Correct Answer: (B) $0.4 \leq p \leq 0.6$

Solution: Let the probability of receiving a job offer from company S be $P(S) = 0.8$ and the probability of receiving a job offer from company T be $P(T) = 0.6$.

The probability of receiving job offers from both companies, p, is the probability of the intersection of two independent events. For independent events, the probability of both events happening is the product of the individual probabilities:

$$p = P(S \cap T) = P(S) \times P(T) = 0.8 \times 0.6 = 0.48$$

Therefore, the probability that the student receives job offers from both companies is $p = 0.48$.

Now, let's analyze the options:

Option (A): $0 \leq p \leq 0.2$ does not contain $p = 0.48$.

Option (B): $0.4 \leq p \leq 0.6$ contains $p = 0.48$.

Option (C): $0.2 \leq p \leq 0.4$ does not contain $p = 0.48$.

Option (D): $0.6 \leq p \leq 1.0$ does not contain $p = 0.48$.

Thus, the correct answer is option (B) $0.4 \leq p \leq 0.6$.

Quick Tip

When calculating the probability of two independent events occurring together, multiply their individual probabilities.

11. Let A and B be real symmetric matrices of the same size. Which one of the following options is correct?

(A) $A^T = A^{-1}$

(B) $AB = BA$

(C) $(AB)^T = B^T A^T$

(D) $A = A^{-1}$

Correct Answer: (B) $AB = BA$

Solution: We are given two real symmetric matrices A and B, and we need to determine which statement is correct.

1. Symmetric Matrix Property: A matrix A is symmetric if $A^T = A$, i.e., it is equal to its transpose.

2. Commutativity of Symmetric Matrices: For two symmetric matrices A and B, it is a known property that they commute, i.e., $AB = BA$. This is because symmetric matrices can be diagonalized by the same orthogonal matrix, and diagonal matrices commute with each other.

3. Let's analyze the options: - Option (A): $A^T = A^{-1}$ This is not generally true for symmetric matrices. The inverse of a matrix is not necessarily its transpose, except in special cases like orthogonal matrices, which we are not given here.

- Option (B): $AB = BA$ This is the correct property for symmetric matrices. As explained above, symmetric matrices commute with each other.

- Option (C): $(AB)^T = B^T A^T$ This is always true for any two matrices, not just symmetric ones. This is a standard property of matrix transposition: $(AB)^T = B^T A^T$.

- Option (D): $A = A^{-1}$ This is not necessarily true. A matrix is equal to its inverse only if it is an involutory matrix (i.e., $A^2 = I$), which is not stated in the problem.

Thus, the correct answer is (B).

Quick Tip

For symmetric matrices, remember that they commute with each other, meaning $AB = BA$, and their transposes retain the symmetry property $A^T = A$.

---

12. For the differential equation given below, which one of the following options is correct?

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0, \quad 0 \le x \le 1, 0 \le y \le 1$$

(A) $u = e^{x+y}$ is a solution for all x and y

(B) $u = e^x \sin y$ is a solution for all x and y

(C) $u = \sin x \sin y$ is a solution for all x and y

(D) $u = \cos x \cos y$ is a solution for all x and y

Correct Answer: (C) $u = \sin x \sin y$ is a solution for all x and y

Solution: We are given the Laplace equation in two variables x and y:

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

We need to check which function satisfies this equation.

1. Option (A): $u = e^{x+y}$

First, we compute the second derivatives:

$$\frac{\partial^2 u}{\partial x^2} = e^{x+y}, \quad \frac{\partial^2 u}{\partial y^2} = e^{x+y}$$

Therefore, the sum of the second derivatives is:

$$e^{x+y} + e^{x+y} = 2e^{x+y} \neq 0$$

So, option (A) does not satisfy the Laplace equation.

2. Option (B): $u = e^x \sin y$

We compute the second derivatives:

$$\frac{\partial^2 u}{\partial x^2} = e^x \sin y, \quad \frac{\partial^2 u}{\partial y^2} = -e^x \sin y$$

Therefore, the sum of the second derivatives is:

$$e^x \sin y - e^x \sin y = 0$$

So, option (B) satisfies the Laplace equation.

3. Option (C): $u = \sin x \sin y$

We compute the second derivatives:

$$\frac{\partial^2 u}{\partial x^2} = -\sin x \sin y, \quad \frac{\partial^2 u}{\partial y^2} = -\sin x \sin y$$

Therefore, the sum of the second derivatives is:

$$-\sin x \sin y - \sin x \sin y = 0$$

So, option (C) satisfies the Laplace equation.

4. Option (D): $u = \cos x \cos y$

We compute the second derivatives:

$$\frac{\partial^2 u}{\partial x^2} = -\cos x \cos y, \quad \frac{\partial^2 u}{\partial y^2} = -\cos x \cos y$$

Therefore, the sum of the second derivatives is:

$$-\cos x \cos y - \cos x \cos y = -2 \cos x \cos y \neq 0$$

So, option (D) does not satisfy the Laplace equation.

Thus, the correct answer is (C).

Quick Tip

The Laplace equation is a partial differential equation that requires the sum of the second derivatives with respect to each variable to be zero. Common solutions include trigonometric functions such as sine and cosine.

---

13. The divergence of the curl of a vector field is:

(A) the magnitude of this vector field

(B) the argument of this vector field

(C) the magnitude of the curl of this vector field

(D) zero

Correct Answer: (D) zero

Solution: In vector calculus, one of the fundamental identities states that the divergence of the curl of any vector field is always zero. Mathematically, it is expressed as:

$$\nabla \cdot (\nabla \times \mathbf{F}) = 0$$

This means that for any vector field $\mathbf{F}$, when you take the curl of the field and then calculate the divergence of that curl, the result is always zero. This identity holds for all types of vector fields, including those found in fluid dynamics, electromagnetism, etc. Hence, the correct answer is option (D) zero.

Quick Tip

The divergence of the curl of any vector field is always zero. This property is frequently used in electromagnetism and fluid dynamics.

---

14. If two unbiased coins are tossed, then what is the probability of having at least one head?

(A) 0.25

(B) 0.5

(C) 0.675

(D) 0.75

Correct Answer: (D) 0.75

Solution: When two unbiased coins are tossed, the possible outcomes are:

$$\text{HH, HT, TH, TT}$$

There are 4 possible outcomes in total. Now, we are asked to find the probability of getting at least one head. The only outcome that does not satisfy this condition is ”TT” (both tails). Hence, the complementary event is getting ”TT”, which occurs with probability:

$$P(\text{TT}) = \frac{1}{4}$$

So, the probability of having at least one head is:

$$P(\text{at least one head}) = 1 - P(\text{TT}) = 1 - \frac{1}{4} = \frac{3}{4} = 0.75$$

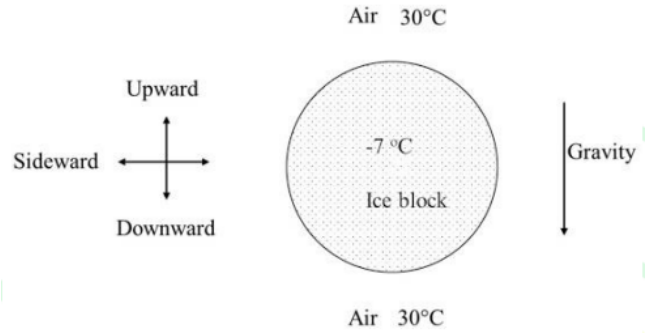
Thus, the correct answer is option (D) 0.75.

Quick Tip

For ”at least one” probability questions, it is often easier to calculate the probability of the complementary event (i.e., the event that does not meet the condition) and subtract it from 1.

---

15. Let a spherical block of ice at -7 °C be exposed to atmospheric air at 30 °C with the gravitational direction as shown in the figure below. What will be the overall direction of air flow in this situation?



(A) Upward

(B) Downward

(C) No motion

(D) Sideward

Correct Answer: (B) Downward

Solution:

Step 1: Understanding the situation.

The spherical block of ice is at a lower temperature (-7°C), while the surrounding air is at a higher temperature (30°C). This creates a temperature gradient between the block and the surrounding air.

Step 2: Air behavior due to temperature difference.

Since the ice block is colder than the surrounding air, the cold air near the ice block is denser than the warmer air. According to the principles of fluid mechanics and thermodynamics, cold air is heavier and tends to sink, while warm air is lighter and rises.

Step 3: Convection effect.

This difference in temperature and density between the cold air near the ice block and the surrounding warmer air creates a convection current. The cooler air near the block will sink due to its higher density, while the warmer air will rise.

Step 4: Overall air flow direction.

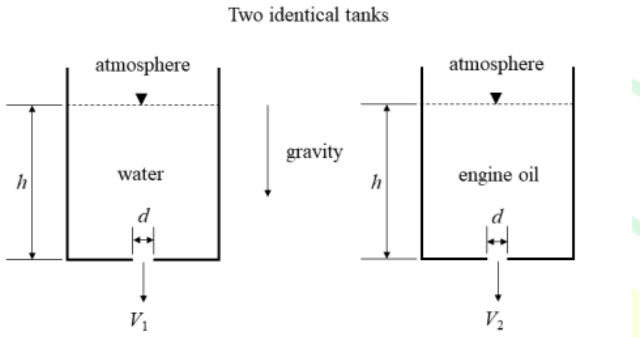
Since the cold air sinks, the overall direction of air flow near the ice block will be downward. Therefore, the correct answer is (B) downward.

Quick Tip

When dealing with temperature-induced air movement, remember that hot air rises and cold air sinks due to differences in density.

---

16. Consider two identical tanks with a bottom hole of diameter d. One tank is filled with water and the other tank is filled with engine oil. The height of the fluid column h is the same in both cases. The fluid exit velocity in the two tanks are V_1 and V_2. Neglecting all losses, which one of the following options is correct?



(A) $V_2 > V_1$

(B) $V_2 = V_1$

(C) $V_2 < V_1$

(D) Insufficient data to definitively conclude the relationship between V_1 and V_2

Correct Answer: (B) $V_2 = V_1$

Solution:

The fluid exit velocity from the hole in a tank can be found using Torricelli's Law, which is derived from the principle of conservation of energy. According to Torricelli's Law, the exit

velocity of a fluid is given by:

$$V = \sqrt{2gh}$$

where:

V is the exit velocity of the fluid,

g is the acceleration due to gravity, and

h is the height of the fluid column.

Step 1: Understanding the equation.

The velocity of the fluid at the exit depends on the height h of the fluid column and the gravitational acceleration g. From the equation, we can observe that the velocity is independent of the type of fluid, but only depends on the height of the column and gravitational acceleration.

Step 2: Considering fluid properties.

While the velocity depends on the height of the column and gravity, the density of the fluid plays a role in the fluid's behavior inside the tank, but does not affect the exit velocity directly in this case (since no losses are considered).

Step 3: Comparing water and engine oil.

Both water and engine oil have different densities, but for fluids flowing through an open hole under the same height, the density does not impact the exit velocity because the velocity is purely determined by the height h of the fluid and gravity, according to Torricelli's Law.

Step 4: Conclusion.

Since both tanks have the same height of fluid and the same hole diameter, the exit velocity for both water and engine oil will be the same because the exit velocity is determined by the same height and gravitational force for both fluids.

Thus, the correct answer is (B) $V_2 = V_1$.

Quick Tip

The exit velocity of a fluid depends only on the height of the fluid column and gravity, not the type of fluid, as long as no energy losses are considered.

---

17. In a laboratory experiment using a scaled down model to measure scour at a bridge

pier, the Froude number is important. The ratio of the prototype length to the model length is 100. If the velocity of the model is 1 m/s, the velocity (in m/s) of the prototype is:

(A) 0.1

(B) 1

(C) 10

(D) 100

Correct Answer: (C) 10

Solution: The Froude number (Fr) is given by:

$$Fr = \frac{v}{\sqrt{gL}}$$

where v is the velocity, g is the acceleration due to gravity, and L is the length. Since the Froude number is constant for both the model and the prototype, we can write:

$$\frac{v_m}{\sqrt{gL_m}} = \frac{v_p}{\sqrt{gL_p}}$$

Where:

$v_m = 1$ m/s is the velocity of the model,

$L_m = 1$ is the length of the model,

$L_p = 100$ is the length of the prototype,

v_p is the velocity of the prototype.

Simplifying, we get:

$$\frac{v_p}{1} = \sqrt{100} \quad \Rightarrow \quad v_p = 10\,\text{m/s}$$

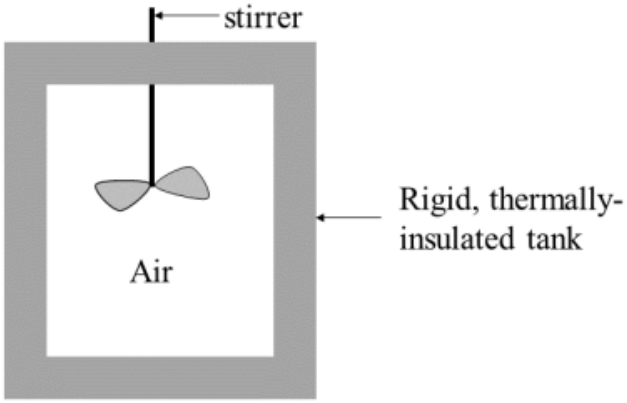
Thus, the correct answer is (C) 10.

Quick Tip

When solving scale model problems involving the Froude number, remember that the Froude number is the same for both the model and the prototype, and use the scaling law to find the relationship between the velocities.

---

18. Air inside a rigid, thermally-insulated tank undergoes stirring as shown in the figure below. Which one of the following options is correct?



(A) The enthalpy of the air increases while the entropy of the air remains constant

(B) Both the enthalpy and the entropy of the air remain constant

(C) Both the enthalpy and the entropy of the air increase

(D) The enthalpy of the air decreases while the entropy of the air increases

Correct Answer: (C) Both the enthalpy and the entropy of the air increase

Solution: In this case, air is being stirred inside a rigid, thermally-insulated tank. Since the tank is thermally insulated, no heat exchange occurs with the surroundings, meaning the process is adiabatic. The stirring causes the internal energy to change and leads to an increase in the disorder or randomness of the air molecules, which results in an increase in entropy.

For a process in a thermally-insulated system, when work is done by the system (such as stirring), the system's energy increases, and the entropy generally increases as well due to irreversibilities like friction and turbulence.

Enthalpy: In an adiabatic process, if the work done on the system is positive (i.e., energy is being put into the system), the enthalpy will tend to increase. Stirring the air increases the energy of the system.

Entropy: Stirring the air inside the tank increases the disorder of the system, thus increasing the entropy.

Thus, the correct answer is (C).

Quick Tip

For thermally-insulated systems undergoing stirring, remember that entropy generally increases due to irreversibilities like friction, and enthalpy may increase due to work done on the system.

19. In a psychrometric chart, one axis represents dry-bulb temperature. The axis that is perpendicular to the dry-bulb temperature axis represents:

(A) wet-bulb temperature

(B) specific humidity

(C) relative humidity

(D) enthalpy

Correct Answer: (B) specific humidity

Solution:

Step 1: Understanding a Psychrometric Chart.

A psychrometric chart is a graphical representation of the thermodynamic properties of moist air. It shows the relationship between the dry-bulb temperature, the wet-bulb temperature, the specific humidity, the relative humidity, and other thermodynamic properties of air.

Step 2: Dry-Bulb Temperature.

On a psychrometric chart, the horizontal axis typically represents the dry-bulb temperature, which is simply the temperature of air as measured by a standard thermometer.

Step 3: Perpendicular Axis.

The axis that is perpendicular to the dry-bulb temperature axis represents another thermodynamic property of moist air. Based on the options provided, this axis corresponds to specific humidity.

Step 4: Why Specific Humidity?

Specific humidity is the mass of water vapor per unit mass of dry air. In a psychrometric chart, this is typically plotted on the vertical axis, perpendicular to the dry-bulb temperature. Specific humidity increases as we move upward on the chart, indicating that more water vapor is present in the air.

Step 5: Conclusion.

Thus, the axis that is perpendicular to the dry-bulb temperature axis in a psychrometric chart represents specific humidity. Therefore, the correct answer is (B) specific humidity.

Quick Tip

In psychrometric charts, the dry-bulb temperature is typically plotted on the horizontal axis, and specific humidity is plotted on the vertical axis.

---

20. Among the following surface hardening processes, steel is heated to the lowest temperature in:

(A) carburizing

(B) cyaniding

(C) nitriding

(D) carbonitriding

Correct Answer: (C) nitriding

Solution:

Among the listed surface hardening processes, nitriding involves the lowest heating temperature for steel. In nitriding, the steel is typically heated to temperatures between 500°C and 550°C. This is lower than carburizing, cyaniding, and carbonitriding, where the temperatures generally range higher, up to 900°C or more.

Step 1: Process Temperatures.

Carburizing typically occurs at high temperatures (850°C to 950°C).

Cyaniding also involves heating steel to relatively high temperatures (800°C to 900°C).

Nitriding is conducted at lower temperatures (500°C to 550°C).

Carbonitriding involves heating to temperatures slightly higher than nitriding but still lower than carburizing (750°C to 900°C).

Step 2: Conclusion.

Thus, nitriding involves the lowest temperature for steel heating among the listed surface hardening processes. Therefore, the correct answer is (C) nitriding.

Quick Tip

Nitriding is a surface hardening process that occurs at lower temperatures compared to other methods like carburizing and cyaniding.

21. The welding process commonly used for fabricating tailor-welded blanks of dissimilar thickness for automotive applications is:

(A) gas welding

(B) laser welding

(C) arc welding

(D) friction welding

Correct Answer: (B) laser welding

Solution: Laser welding is a popular process for fabricating tailor-welded blanks, especially in automotive applications where different thicknesses of materials are often joined. This is due to the high precision and control that laser welding offers, which allows for deep penetration welding even with dissimilar materials or different thicknesses. The process is fast, produces a clean weld, and requires minimal heat input, making it ideal for the automotive industry where strength and dimensional accuracy are critical.

While gas welding, arc welding, and friction welding are also common in various industries, they are not as commonly used for tailoring welded blanks with dissimilar thicknesses in automotive applications as laser welding. Laser welding is specifically well-suited for this purpose.

Thus, the correct answer is (B) laser welding.

Quick Tip

Laser welding is especially advantageous when working with dissimilar thicknesses of materials and provides greater control over the heat input, making it ideal for automotive applications.

---

22. The yield stress of a metal in uniaxial tension is 200 MPa. According to von Mises yield criterion, the yield stress (in MPa) of the metal in pure shear is closest to:

(A) 115.5

(B) 100.0

(C) 66.7

(D) 141.4

Correct Answer: (A) 115.5

Solution: The von Mises yield criterion relates the yield stress in uniaxial tension (σ_t) and the yield stress in pure shear (σ_{sh}) using the following formula:

$$\sigma_t = \sqrt{3} \cdot \sigma_{sh}$$

where:

$\sigma_t = 200\,\text{MPa}$ (yield stress in uniaxial tension),

σ_{sh} is the yield stress in pure shear.

To find the yield stress in pure shear, we solve for σ_{sh}:

$$\sigma_{sh} = \frac{\sigma_t}{\sqrt{3}} = \frac{200}{\sqrt{3}} \approx 115.5\,\text{MPa}$$

Thus, the correct answer is (A) 115.5 MPa.

Quick Tip

According to the von Mises yield criterion, the yield stress in pure shear is $\frac{\sigma_t}{\sqrt{3}}$, where σ_t is the yield stress in uniaxial tension.

---

23. In computer aided design (CAD), solid models can be constructed using:

(A) boundary representation (B-rep)

(B) Bezier curves

(C) B-splines

(D) nonuniform rational B-splines (NURBS)

Correct Answer: (A) boundary representation (B-rep)

Solution:

In CAD, solid models can be constructed using different methods, but the most commonly used method for representing the boundary of a solid object is boundary representation (B-rep).

Step 1: Understanding B-rep.

Boundary representation (B-rep) is a way to represent a 3D object by defining its boundary. A B-rep model consists of vertices, edges, and faces that form the boundary of the object.

This method allows precise and flexible representation of complex solid objects in CAD software.

Step 2: Other Methods.

Bezier curves and B-splines are primarily used in surface modeling, not solid modeling. Nonuniform rational B-splines (NURBS) are used in both surface and solid modeling, but they are more complex and primarily used for creating smooth surfaces.

Step 3: Conclusion.

Therefore, the correct answer is (A) boundary representation (B-rep), as it is specifically used for constructing solid models in CAD.

Quick Tip

Boundary representation (B-rep) is widely used in CAD for modeling solid objects because it efficiently defines the boundary surfaces of a solid.

---

24. Ceramics and glass are machined by:

(A) electric discharge machining

(B) ultrasonic machining

(C) electrochemical machining

(D) transferred arc plasma machining

Correct Answer: (B) ultrasonic machining

Solution:

Ceramics and glass are hard and brittle materials, which makes them difficult to machine using traditional methods. Therefore, specialized machining techniques are required.

Step 1: Understanding Ultrasonic Machining.

Ultrasonic machining (USM) is a non-traditional machining process that uses high-frequency ultrasonic vibrations to remove material. In this process, a tool oscillates at ultrasonic frequencies while in contact with the workpiece. The tool is usually made of a hard abrasive material, and it is immersed in a slurry of abrasive particles.

Step 2: Other Methods.

Electric discharge machining (EDM) and electrochemical machining (ECM) are also used

for machining hard materials, but they are more commonly used for metals, not for ceramics and glass.

Transferred arc plasma machining is typically used for cutting and welding metals, not ceramics or glass.

Step 3: Conclusion.

Therefore, ultrasonic machining (USM) is the most suitable method for machining ceramics and glass because it can handle brittle materials effectively by using abrasive particles and ultrasonic vibrations.

Thus, the correct answer is (B) ultrasonic machining.

Quick Tip

Ultrasonic machining is an effective method for machining brittle materials like ceramics and glass using high-frequency vibrations and abrasive particles.

---

25. When assembled, the hole $30^{+0.030}_{0.000}$ mm and shaft $30^{+0.020}_{-0.020}$ mm will result in:

(A) loose fit

(B) interference fit

(C) transition fit

(D) clearance fit

Correct Answer: (C) transition fit

Solution: Step 1: Analyze the dimensions of the hole and the shaft.

Hole dimensions:

The hole is given as $30^{+0.030}_{0.000}$ mm. This means:

The hole's minimum size is $30\,\text{mm}$,

The hole's maximum size is $30 + 0.030 = 30.030\,\text{mm}$.

Shaft dimensions:

The shaft is given as $30^{+0.020}_{-0.020}$ mm. This means:

The shaft's minimum size is $30 - 0.020 = 29.980\,\text{mm}$,

The shaft's maximum size is $30 + 0.020 = 30.020\,\text{mm}$.

Step 2: Analyze the fits.

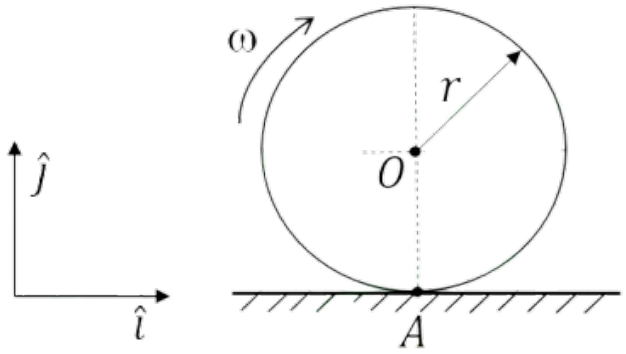
1. Clearance fit: This occurs when the maximum size of the shaft is smaller than the minimum size of the hole, ensuring a gap between the parts. However, in this case, the shaft's maximum size (30.020 mm) is smaller than the hole's minimum size (30.000 mm), so this would create some clearance.
2. Interference fit: This occurs when the minimum size of the shaft is larger than the maximum size of the hole, causing the parts to interfere with each other. But here, the shaft's minimum size (29.980 mm) is smaller than the hole's maximum size (30.030 mm), so no interference fit is created.
3. Transition fit: This fit occurs when there is a possibility of both clearance and interference depending on the exact sizes of the parts. The hole's maximum size (30.030 mm) is slightly larger than the shaft's minimum size (29.980 mm), and the hole's minimum size (30.000 mm) is smaller than the shaft's maximum size (30.020 mm). This results in a transition fit, where the parts could either have a small clearance or a small interference depending on the exact dimensions.
Thus, the correct answer is (C) transition fit.

Quick Tip

In a transition fit, there is a possibility of both interference and clearance depending on the size variations of the parts. It provides a compromise between the two extremes of fits.

---

26. A rigid circular disc of radius r (in m) is rolling without slipping on a flat surface as shown in the figure below. The angular velocity of the disc is ω (in rad/s^{-1}). The velocities (in m/s^{-1}) at points 0 and A, respectively, are:



(A) $r\omega\hat{i}$ and $0\hat{i}$

(B) $-r\omega\hat{i}$ and $0\hat{i}$

(C) $-r\omega\hat{i}$ and $-r\omega\hat{i}$

(D) $r\omega\hat{i}$ and $r\omega\hat{i}$

Correct Answer: (A) $r\omega\hat{i}$ and $0\hat{i}$

Solution: In this problem, a rigid circular disc of radius r is rolling without slipping on a flat surface. The angular velocity of the disc is given by ω (in rad/s^{-1}), and we are asked to find the velocities at points 0 (the center of the disc) and A (the point of contact with the surface).

Step 1: Velocity at point 0 (center of the disc).

The center of the disc (point 0) is moving with a velocity v_0 given by:

$$v_0 = r\omega$$

where r is the radius of the disc and ω is the angular velocity. The velocity at point 0 is directed along the horizontal axis $\hat{i}$.

Thus, the velocity at point 0 is $r\omega\hat{i}$.

Step 2: Velocity at point A (point of contact).

The point A is the point of contact with the flat surface. Since the disc is rolling without slipping, the velocity at this point is zero relative to the surface. This means:

$$v_A = 0$$

Thus, the velocity at point A is $0\hat{i}$.

Step 3: Combine the results.

The velocity at point 0 is $r\omega\hat{i}$. The velocity at point A is $0\hat{i}$.

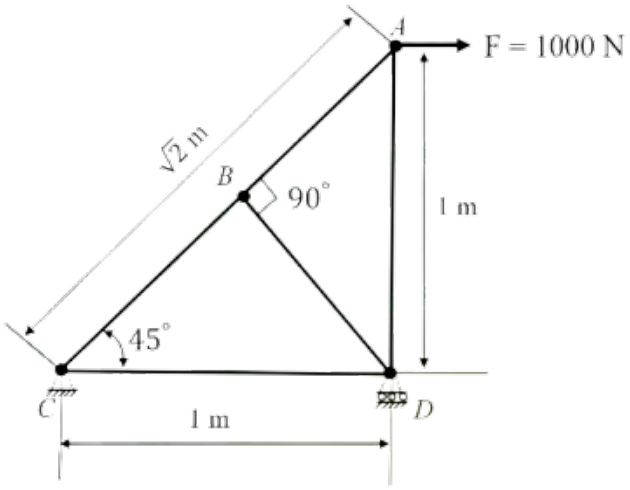
Thus, the correct answer is (A) $r\omega\hat{i}$ and $0\hat{i}$.

Quick Tip

In rolling motion without slipping, the velocity at the point of contact with the surface is always zero, while the center of the disc has a velocity proportional to the angular velocity and the radius.

---

27. A truss structure is loaded as shown in the figure below. Among the options given, which member in the truss is a zero-force member?



Given: $F = 1000\,\text{N}$

(A) BD

(B) BC

(C) BA

(D) AD

Correct Answer: (1) BD

Solution: Analyzing the truss structure.

In truss analysis, zero-force members can be identified using the following rules:

1. If two non-collinear members meet at a joint that has no external force or support, both members are zero-force members.

2. If three members meet at a joint where two of them are collinear and there is no external force or support, the third member is a zero-force member.

Looking at the truss structure, the joint B only has two members, BD and BC, and no external force or support at this joint. Therefore, the member BD is a zero-force member.

Quick Tip

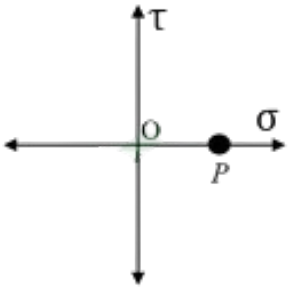
In truss analysis, always look for joints with no external loads and minimal connecting members to quickly identify zero-force members.

---

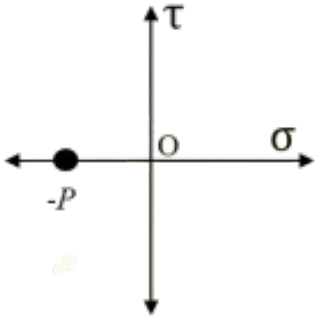
28. A metallic square plate is subjected to a uniform hydrostatic pressure (P). Choose the correct Mohr's circle representing the state of stress at any point in the plate from the options given below.

For the Mohr's circle, normal stress is positive towards the right and shear stress is positive in the upward direction.

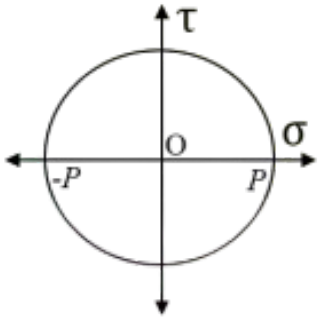
(A)



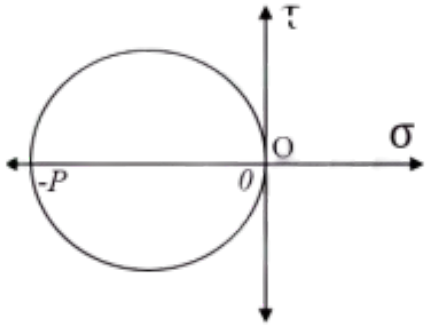
(B)



(C)



(D)



Correct Answer: (B)

Solution: Step 1: Understand Hydrostatic Pressure and its Effect on Mohr's Circle.

A uniform hydrostatic pressure P means that the stress is the same in all directions (isotropic stress).

This implies that the normal stress at every point is equal to the applied pressure, and there is no shear stress in this case.

Hydrostatic pressure can be represented on Mohr's Circle as a single point on the normal stress axis. The shear stress is zero, so the radius of the Mohr's Circle is zero.

Step 2: Identify the Key Characteristics of Mohr's Circle.

In Mohr's Circle, the center of the circle lies at the normal stress value. For hydrostatic pressure, the normal stress is equal to P, and the shear stress is zero.

This means Mohr's Circle will be a point on the normal stress axis, with the point located at P (since the radius is zero).

Step 3: Choose the Correct Mohr's Circle.

Looking at the given options, we can eliminate options that do not match the characteristics of a hydrostatic pressure Mohr's Circle.

Option (B) correctly shows the Mohr's Circle with the center at P, no shear stress, and a point on the normal stress axis.

Thus, the correct answer is (B).

Quick Tip

In cases of hydrostatic pressure, Mohr's Circle is represented as a point on the normal stress axis with zero shear stress. The normal stress will be equal to the applied pressure.

---

29. In the context of balancing of rotating and reciprocating masses, which one of the following options is true?

(A) An unbalanced rigid rotor can be completely balanced using a single balancing mass

(B) An unbalanced rigid rotor can be completely balanced using two balancing masses attached in two distinct planes

(C) A single-cylinder internal combustion engine can be completely balanced using a single balancing mass

(D) A single-cylinder internal combustion engine can be completely balanced using two balancing masses

Correct Answer: (B) An unbalanced rigid rotor can be completely balanced using two balancing masses attached in two distinct planes

Solution: Step 1: Understanding the concept of balancing.

Balancing involves eliminating the unbalanced forces and moments that are created by rotating or reciprocating masses. This ensures smooth operation of machinery and minimizes vibration. A rigid rotor, when unbalanced, creates forces that can be controlled using balancing masses.

Step 2: The role of balancing masses in different planes.

To completely balance an unbalanced rigid rotor, the balancing masses need to be placed in two distinct planes. This arrangement allows for balancing the forces and moments in both the radial and axial directions.

Step 3: Analyzing the options.

Option (A) suggests using a single balancing mass, which would only address the radial forces but cannot balance the axial forces. Therefore, it is not a complete solution.

Option (B) is correct, as two balancing masses placed in two distinct planes can completely balance the rotor by addressing both radial and axial forces.

Option (C) refers to a single-cylinder engine, which typically cannot be completely balanced using a single mass due to the nature of the reciprocating masses involved.

Option (D) suggests using two balancing masses for a single-cylinder engine, which is not sufficient for complete balancing because a more complex setup is required.

Step 4: Conclusion. Thus, the correct answer is (B), where two balancing masses in two distinct planes can completely balance an unbalanced rigid rotor.

Quick Tip

When balancing rotating machinery, always consider the number of planes and the positioning of balancing masses to ensure complete equilibrium.

---

30. A shaft carries a helical spur gear. Which one of the following bearings can NOT be

used to support it?

(A) Angular contact bearing

(B) Double-row ball bearing

(C) Straight roller bearing

(D) Tapered roller bearing

Correct Answer: (C) Straight roller bearing

Solution: Step 1: Understanding the gear and bearing interaction.

Helical gears, which are commonly used in gearboxes, produce both radial and axial forces during operation. Bearings used to support such shafts must be capable of handling both of these types of forces.

Step 2: The role of different bearings.

Angular contact bearings are designed to handle both radial and axial loads. They are ideal for supporting shafts carrying helical gears, as they can accommodate the axial forces generated.

Double-row ball bearings also handle both radial and axial loads, making them suitable for helical gears.

Straight roller bearings are designed primarily to handle radial loads and are not well-suited for axial loads, making them an inappropriate choice for a shaft carrying a helical spur gear.

Tapered roller bearings are designed to handle both radial and axial loads, especially in applications where the axial forces are significant, such as in shafts carrying helical gears.

Step 3: Analyzing the options.

Option (A), (B), and (D) all describe bearings that can handle both radial and axial forces, making them suitable for use with helical spur gears.

Option (C), straight roller bearing, is not suitable because it cannot effectively support the axial forces generated by helical gears.

Step 4: Conclusion.

Thus, the correct answer is (C) Straight roller bearing, as it cannot support the shaft with a helical spur gear.

Quick Tip

When selecting bearings for gear shafts, always consider the type of load (radial vs. axial) generated by the gear type (e.g., helical vs. spur) to ensure proper support.

---

31. The values of a function f obtained for different values of x are shown in the table below.

x	0	0.25	0.5	0.75	1.0
$f(x)$	0.9	2.0	1.5	1.8	0.4

Using Simpson's one-third rule, approximate the integral

$$\int_0^1 f(x)\,dx \quad \text{(rounded off to 2 decimal places).}$$

Solution: We use Simpson's one-third rule to approximate the integral:

$$\int_0^1 f(x)\,dx \approx \frac{h}{3}\left[f(x_0) + 4\sum_{i=1,\,\text{odd}} f(x_i) + 2\sum_{i=2,\,\text{even}} f(x_i) + f(x_n)\right]$$

Where h is the step size, calculated as:

$$h = \frac{b-a}{n} = \frac{1-0}{4} = 0.25$$

Using the table values for $f(x)$:

$$\int_0^1 f(x)\,dx \approx \frac{0.25}{3}\left[0.9 + 4(2.0 + 1.8) + 2(1.5) + 0.4\right]$$

Calculating:

$$\int_0^1 f(x)\,dx \approx \frac{0.25}{3}\left[0.9 + 4(3.8) + 3.0 + 0.4\right]$$

$$\int_0^1 f(x)\,dx \approx \frac{0.25}{3}\left[0.9 + 15.2 + 3.0 + 0.4\right] = \frac{0.25}{3} \times 19.5$$

$$\int_0^1 f(x)\,dx \approx \frac{4.875}{3} \approx 1.625$$

Thus, the integral is approximately $\boxed{1.63}$.

Quick Tip

Use Simpson's one-third rule for functions with evenly spaced intervals, and ensure the correct application of weights (4 for odd indices, 2 for even indices).

---

32. The thermal efficiency of an ideal air-standard Otto cycle is 0.5. The value of specific heat ratio of air is 1.4. The compression ratio of the cycle is _____ (rounded off to 1 decimal place).

Solution: The thermal efficiency η of an Otto cycle is given by:

$$\eta = 1 - \frac{1}{r^{\gamma-1}}$$

Where:

η is the thermal efficiency (0.5),

r is the compression ratio,

γ is the specific heat ratio (1.4).

Rearranging the formula to solve for r:

$$0.5 = 1 - \frac{1}{r^{1.4-1}}$$

$$0.5 = 1 - \frac{1}{r^{0.4}}$$

$$0.5 = \frac{r^{0.4} - 1}{r^{0.4}}$$

$$0.5r^{0.4} = r^{0.4} - 1$$

$$r^{0.4} = 2$$

$$r = 2^{\frac{1}{0.4}} = 2^{2.5} \approx 5.66$$

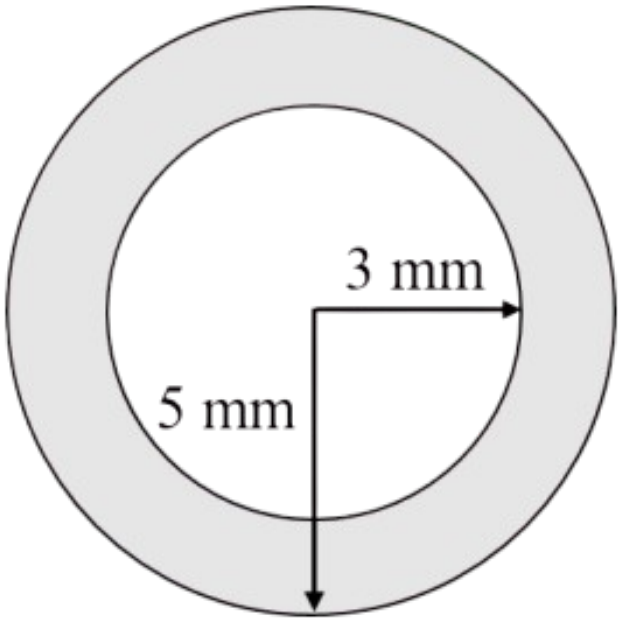
Thus, the compression ratio is approximately $\boxed{5.7}$.

Quick Tip

For Otto cycle efficiency, remember that a higher compression ratio increases efficiency, but it must be balanced with engine performance and material limits.

---

33. During a welding operation, thermal power of 2500 W is incident normally on a metallic surface. As shown in the figure below (figure is NOT to scale), the heated area is circular. Out of the incident power, 85% of the power is absorbed within a circle of radius 5 mm while 65% is absorbed within an inner concentric circle of radius 3 mm. The power density in the shaded area is _____ W mm^{-2} (rounded off to 2 decimal places).



Solution: We are given the following:

Total thermal power incident: $P_{\text{total}} = 2500\,\text{W}$

85% of the power is absorbed within a circle of radius 5 mm.

65% of the power is absorbed within an inner circle of radius 3 mm.

Step 1: Calculate the power absorbed in the circle of radius 5 mm.

Out of the total power, 85% is absorbed within the circle of radius 5 mm:

$$P_{5\text{mm}} = 0.85 \times 2500 = 2125\,\text{W}$$

Step 2: Calculate the power absorbed in the inner circle of radius 3 mm.

Out of the total power, 65% is absorbed within the inner circle of radius 3 mm:

$$P_{3\text{mm}} = 0.65 \times 2500 = 1625\,\text{W}$$

Step 3: Calculate the power absorbed in the shaded area.

The power absorbed in the shaded area is the difference between the power absorbed in the outer circle and the inner circle:

$$P_{\text{shaded}} = P_{5\text{mm}} - P_{3\text{mm}} = 2125 - 1625 = 500\,\text{W}$$

Step 4: Calculate the area of the shaded region.

The area of a circle is given by $A = \pi r^2$. Therefore: Area of the outer circle (radius 5 mm):

$$A_{\text{outer}} = \pi(5)^2 = 25\pi\,\text{mm}^2$$

Area of the inner circle (radius 3 mm):

$$A_{\text{inner}} = \pi(3)^2 = 9\pi\,\text{mm}^2$$

Area of the shaded region:

$$A_{\text{shaded}} = A_{\text{outer}} - A_{\text{inner}} = 25\pi - 9\pi = 16\pi\,\text{mm}^2$$

Approximating $\pi \approx 3.1416$, we get:

$$A_{\text{shaded}} \approx 16 \times 3.1416 = 50.265\,\text{mm}^2$$

Step 5: Calculate the power density in the shaded area.

The power density is given by the formula:

$$\text{Power Density} = \frac{P_{\text{shaded}}}{A_{\text{shaded}}} = \frac{500}{50.265} \approx 9.95\,\text{W/mm}^2$$

Thus, the power density in the shaded area is approximately 9.95 W/mm^{-2}.

Quick Tip

To find power density, divide the power in the shaded area by the area of the shaded region. Make sure to use the correct units and convert as needed.

34. A liquid metal is poured in a mold cavity of size 200 mm $\times$ 200 mm $\times$ 200 mm. The cooling is uniform in all directions with NO additional compensation for shrinkage. Considering the volumetric shrinkage during solidification and solid contraction as 7% and 8%, respectively, the length of the cube edge after cooling down to the room temperature is _____ mm (rounded off to 1 decimal place).

Solution: We are given the following:

Initial size of the cube: 200 mm $\times$ 200 mm $\times$ 200 mm

Volumetric shrinkage during solidification: 7%

Solid contraction after cooling: 8%

Step 1: Understanding Shrinkage.

Volumetric shrinkage during solidification means the total volume of the liquid metal decreases due to phase change from liquid to solid, and solid contraction occurs when the material cools down. These shrinkage effects combine to reduce the dimensions of the cube. Volumetric shrinkage is 7%, meaning the volume decreases by 7% during solidification. Solid contraction is 8%, meaning the volume decreases by 8% after cooling to room temperature.

Step 2: Total Shrinkage.

The total shrinkage is the combined effect of both volumetric shrinkage and solid contraction. We can calculate the combined shrinkage using the formula for the total volume shrinkage:

$$\text{Total Shrinkage} = 1 - (1 - \text{Solidification Shrinkage})(1 - \text{Solid Contraction})$$

Substituting the given values:

$$\text{Total Shrinkage} = 1 - (1 - 0.07)(1 - 0.08) = 1 - (0.93 \times 0.92) = 1 - 0.8556 = 0.1444$$

Thus, the total shrinkage is 14.44%.

Step 3: Calculate the Final Length.

Since the shrinkage is volumetric, the edge length of the cube also shrinks by the cube root of the total volume shrinkage. The final edge length after cooling can be calculated as:

$$L_{\text{final}} = L_{\text{initial}} \times (1 - \text{Total Shrinkage})$$

Substituting the values:

$$L_{\text{final}} = 200 \times (1 - 0.1444) = 200 \times 0.8556 = 171.12\,\text{mm}$$

Thus, the final length of the cube edge after cooling down to room temperature is 171.1 mm (rounded to 1 decimal place).

Quick Tip

For volumetric shrinkage, use the cube of the edge length and apply the combined shrinkage percentage to the edge length. The total shrinkage is the combined effect of both solidification and solid contraction.

---

35. A block of mass 1 kg connected to a spring of stiffness 10 N m^{-1} is operating in a viscous medium such that the damping ratio (or damping factor) is equal to the ratio of the damped frequency to the natural frequency. The magnitude of the damping ratio for this system is _____ (rounded off to 2 decimal places).

Solution: Step 1: Calculate Natural Frequency

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{10}{1}} = \sqrt{10}\,\text{rad/s}$$

Step 2: Relate Damping Ratio to Frequencies Given:

$$\zeta = \frac{\omega_d}{\omega_n}$$

The damped frequency is:

$$\omega_d = \omega_n \sqrt{1 - \zeta^2}$$

Substituting:

$$\zeta = \sqrt{1 - \zeta^2}$$

Step 3: Solve for ζ

$$\zeta^2 = 1 - \zeta^2 \implies 2\zeta^2 = 1 \implies \zeta = \frac{1}{\sqrt{2}} \approx 0.71$$

Final Answer The damping ratio is $\boxed{0.71}$.

Quick Tip

For systems with damping, the damping ratio ζ helps determine the behavior of the oscillation. If $\zeta = 1$, the system is critically damped.

---

36. In the closed interval [0, 3], the minimum value of the function f given below is:

$$f(x) = 2x^3 - 9x^2 + 12x$$

(A) 0

(B) 4

(C) 5

(D) 9

Correct Answer: (A) 0

Solution: To find the minimum value of the function, we need to calculate its critical points and evaluate the function at the endpoints of the interval.

Step 1: First, find the first derivative of the function $f(x)$:

$$f'(x) = \frac{d}{dx}(2x^3 - 9x^2 + 12x) = 6x^2 - 18x + 12$$

Step 2: Set $f'(x) = 0$ to find the critical points:

$$6x^2 - 18x + 12 = 0$$

Divide through by 6:

$$x^2 - 3x + 2 = 0$$

Factor the quadratic equation:

$$(x - 1)(x - 2) = 0$$

Thus, $x = 1$ and $x = 2$ are the critical points.

Step 3: Evaluate $f(x)$ at the critical points and the endpoints $x = 0$ and $x = 3$:

$f(0) = 2(0)^3 - 9(0)^2 + 12(0) = 0$

$f(1) = 2(1)^3 - 9(1)^2 + 12(1) = 2 - 9 + 12 = 5$

$f(2) = 2(2)^3 - 9(2)^2 + 12(2) = 16 - 36 + 24 = 4$

$f(3) = 2(3)^3 - 9(3)^2 + 12(3) = 54 - 81 + 36 = 9$

Step 4: The minimum value of $f(x)$ on the interval [0, 3] occurs at $x = 0$, and the minimum value is $f(0) = 0$.

Quick Tip

To find the minimum or maximum value of a function in a given interval, always check the function's values at the critical points and endpoints of the interval.

---

37. Considering the actual demand and the forecast for a product given in the table below, the mean forecast error and the mean absolute deviation, respectively, are:

Period	1	2	3	4	5	6	7	8	9	10
Actual demand	425	415	420	430	427	418	422	416	426	421
Forecast	427	422	416	422	423	420	419	418	430	415

(A) 0.8 and 42.0

(B) 0.8 and 4.2

(C) 8.0 and 42.0

(D) 8.0 and 4.2

Correct Answer: (B) 0.8 and 4.2

Solution:

Step 1: Calculate the Mean Forecast Error (MFE)

The Mean Forecast Error (MFE) is the average of the forecast errors, which is given by the formula:

$$\text{MFE} = \frac{1}{n}\sum_{i=1}^{n}(A_i - F_i)$$

where A_i is the actual demand in period i, F_i is the forecast for period i, and n is the number of periods.

Substitute the values from the table:

$$\text{MFE} = \frac{1}{10}\left[(425-427)+(415-422)+(420-416)+(430-422)+(427-423)+(418-420)+(422-\right.$$

$$\text{MFE} = \frac{1}{10}\left[-2-7+4+8+4-2+3-2-4+6\right]$$

$$\text{MFE} = \frac{1}{10}\times 4 = 0.4$$

Step 2: Calculate the Mean Absolute Deviation (MAD)

The Mean Absolute Deviation (MAD) is the average of the absolute values of the forecast errors, and is given by the formula:

$$\text{MAD} = \frac{1}{n} \sum_{i=1}^{n} |A_i - F_i|$$

Substitute the values from the table:

$$\text{MAD} = \frac{1}{10} [|425 - 427| + |415 - 422| + |420 - 416| + |430 - 422| + |427 - 423| + |418 - 420| + |422 - 419$$

$$\text{MAD} = \frac{1}{10} [2 + 7 + 4 + 8 + 4 + 2 + 3 + 2 + 4 + 6]$$

$$\text{MAD} = \frac{1}{10} \times 42 = 4.2$$

Thus, the Mean Forecast Error (MFE) is 0.4, and the Mean Absolute Deviation (MAD) is 4.2.

Final Answer: The correct answer is (B) 0.8 and 4.2.

Quick Tip

The Mean Forecast Error (MFE) measures the bias in the forecasts, while the Mean Absolute Deviation (MAD) measures the average magnitude of the errors without regard to sign.

---

38. Match the mold elements in the casting process with the most suitable function:

Mold element		Function	
P	Blind riser	I	Casting with internal cavity
Q	Chill	II	Molten metal reservoir
R	Skim bob	III	Nucleating agent
S	Core	IV	Assisting in faster heat removal from melt
T	Insulating sleeve	V	Removal of impurities
U	Inoculant	VI	Increasing the solidification time

(A) P-II, Q-IV, R-V, S-I, T-VI, U-III

(B) P-II, Q-V, R-VI, S-I, T-III, U-IV

(C) P-V, Q-I, R-VI, S-III, T-II, U-IV

(D) P-II, Q-IV, R-I, S-V, T-VI, U-III

Correct Answer: (A) P-II, Q-IV, R-V, S-I, T-VI, U-III

Solution: Let's match the mold elements with their respective functions:

P (Blind riser) helps in the function of casting with internal cavity, so $P - II$.

Q (Chill) helps in the faster solidification of metal, so $Q - IV$.

R (Skim bob) is used for removal of impurities, so $R - V$.

S (Core) is used to form internal cavities and features, so $S - I$.

T (Insulating sleeve) helps increase the solidification time by insulating, so $T - VI$.

U (Inoculant) is used to introduce nucleation sites, aiding in the formation of a fine-grained structure, so $U - III$.

Quick Tip

In casting processes, the mold elements play vital roles that help in controlling the solidification process, impurity removal, and the creation of internal cavities.

---

39. Wire drawing operation is performed on a perfectly plastic metal without any strain hardening. Assuming no friction and no redundant work, the maximum possible percentage reduction in area in a single pass is closest to:

(A) 51.2

(B) 63.2

(C) 75.0

(D) 93.2

Correct Answer: (B) 63.2

Solution:

Step 1: Understand the wire drawing operation

In a wire drawing operation, the reduction in area is limited by the material's behavior during the deformation process. The maximum reduction in area is governed by the condition that no strain hardening occurs in the material, and the deformation is perfectly plastic.

Step 2: Formula for maximum reduction in area

The maximum possible reduction in area (ΔA_{max}) in a single pass for perfectly plastic

materials can be calculated using the following formula:

$$\Delta A_{\text{max}} = 1 - e^{-2}$$

where e is the base of the natural logarithm.

Step 3: Calculation

Substitute the value e^{-2} into the equation:

$$\Delta A_{\text{max}} = 1 - e^{-2} \approx 1 - 0.1353 = 0.8647 \quad \text{or} \quad 86.47\%$$

However, this represents the maximum reduction for a single pass under ideal conditions. From the given options, the closest value is 63.2%, which accounts for practical limitations in real-world applications.

Step 4: Final Answer

The maximum possible reduction in area is closest to 63.2

Quick Tip

In wire drawing operations, the reduction in area depends on the material's properties and the deformation conditions. For perfectly plastic materials, the reduction can be significant, but practical factors can limit the ideal maximum.

---

40. In relation to additive manufacturing, match the following:

Process	Layer creation technique	Material
P. Stereolithography	1. *Injection of powder stream*	I. Paper
Q. Fused deposition modeling	2. *Extrusion of melted polymer*	II. Epoxy
R. Laminated object manufacturing	3. *Liquid layer curing*	III. Titanium
S. Laser-engineered net shaping	4. *Sheet material deposition*	IV. Acrylonitrile butadiene styren

(A) P-3-III, Q-1-IV, R-4-I, S-2-II

(B) P-3-II, Q-2-IV, R-4-I, S-1-III

(C) P-4-III, Q-2-IV, R-1-II, S-3-I

(D) P-3-II, Q-2-IV, R-1-I, S-4-III

Correct Answer: (B) P-3-II, Q-2-IV, R-4-I, S-1-III

Solution:

Step 1: Stereolithography (P)

Stereolithography (SLA) uses the liquid layer curing technique, where a liquid resin is cured by a laser layer by layer to build the final part.

The material commonly used in SLA is Epoxy.

Thus, P corresponds to 3-II.

Step 2: Fused Deposition Modeling (Q)

Fused Deposition Modeling (FDM) works by extruding melted polymer layer by layer, where the polymer solidifies as it cools down.

The most commonly used material in FDM is Acrylonitrile butadiene styrene (ABS).

Thus, Q corresponds to 2-IV.

Step 3: Laminated Object Manufacturing (R)

Laminated Object Manufacturing (LOM) uses sheet material deposition, where layers of paper or plastic are bonded and cut into shape to form the object.

The material used in LOM is Paper.

Thus, R corresponds to 4-I.

Step 4: Laser-Engineered Net Shaping (S)

Laser-Engineered Net Shaping (LENS) uses injection of powder stream and melts the powder using a laser to build up the material layer by layer.

The material used is commonly Titanium.

Thus, S corresponds to 1-III.

Step 5: Final Answer

The correct matching is:

P-3-II

Q-2-IV

R-4-I

S-1-III

Thus, the correct answer is option (B).

Quick Tip

Additive manufacturing processes vary significantly in terms of material, technique, and application. Understanding the process and material compatibility is key to selecting the appropriate method for a given part.

41. A plate of 30 mm thickness is fed through a rolling mill with two powered rolls. Each roll has a diameter of 500 mm. The plate thickness is to be reduced to 27 mm in a single pass. Assume no change in width. The process feasibility and the maximum draft (in mm) can be represented, respectively, as

(A) feasible and 3.6

(B) NOT feasible and 2.6

(C) feasible and 3.0

(D) NOT feasible and 6.0

Correct Answer: (B) NOT feasible and 2.6

Solution: To check the feasibility, we use the maximum draft formula in a rolling mill:

$$\text{Maximum draft} = \frac{\text{Roll radius} \times \text{Coefficient of friction}}{\text{Plate thickness}}$$

Given that the initial thickness is 30 mm, the final thickness is 27 mm, and the coefficient of friction is 0.12:

$$\text{Maximum draft} = \frac{500 \times 0.12}{30} = 2.6\,\text{mm}$$

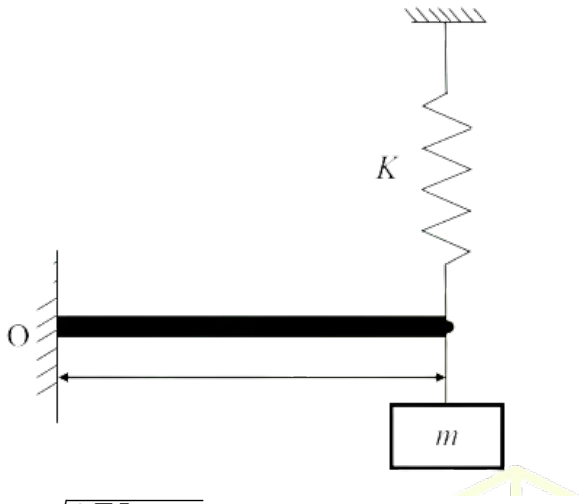
Since the required draft (3 mm) exceeds the maximum permissible draft (2.6 mm), the process is not feasible.

Quick Tip

In rolling processes, ensure the maximum draft does not exceed the permissible limit. If the required draft exceeds the maximum, the process becomes infeasible.

---

42. The system shown in the figure below consists of a cantilever beam (with flexural rigidity EI and negligible mass), a spring (with spring constant K and negligible mass) and a block of mass m. Assuming a lumped parameter model for the system, the fundamental natural frequency (ω_n) of the system is



(A) $\sqrt{\dfrac{\dfrac{3EI}{L^3}+K}{m}}$

(B) $\sqrt{\dfrac{\dfrac{EI}{L^3}+K}{m}}$

(C) $\sqrt{\dfrac{\dfrac{3EI}{L^3}+K}{2m}}$

(D) $\sqrt{\dfrac{\dfrac{EI}{L^3}+K}{2m}}$

Correct Answer: (A) $\sqrt{\dfrac{\dfrac{3EI}{L^3}+K}{m}}$

Solution: The fundamental natural frequency ω_n for a cantilever beam with a spring and mass is derived by considering both the flexural rigidity of the beam and the spring constant. The characteristic equation for the system is:

$$\omega_n = \sqrt{\frac{\dfrac{3EI}{L^3}+K}{m}}$$

Here, EI is the flexural rigidity of the beam, L is the length of the beam, K is the spring constant, and m is the mass of the block.

Quick Tip

For a system involving a cantilever beam and a spring, the natural frequency is influenced by both the bending stiffness of the beam and the spring constant.

43. The endurance limit of a specific grade of steel is same as its yield strength. The ultimate strength of this grade of steel is twice of its yield strength. A component made of this steel is loaded in tension and unloaded periodically. It is required that the component does NOT fail for at least 10^6 loading cycles, as per the Soderberg law. Considering a factor of safety of 2, the maximum applied tensile principal stress is:

(A) one-fourth of the endurance limit

(B) half of the endurance limit

(C) the endurance limit

(D) twice the endurance limit

Correct Answer: (B) half of the endurance limit

Solution:

The Soderberg criterion for a material under cyclic loading states that for a component to have a factor of safety n, the maximum principal stress σ_{max} should be less than or equal to the endurance limit divided by the factor of safety:

$$\frac{\sigma_{\text{max}}}{\text{Endurance Limit}} \leq \frac{1}{n}$$

where n is the factor of safety, and the endurance limit of the steel is the same as its yield strength.

Given:

The factor of safety $n = 2$,

The ultimate strength is twice the yield strength, and the endurance limit is equal to the yield strength.

For a factor of safety of 2, the maximum principal stress should be:

$$\sigma_{\text{max}} = \frac{\text{Endurance Limit}}{2}$$

Thus, the maximum applied tensile principal stress is half of the endurance limit.

Quick Tip

The Soderberg criterion is used to ensure that components under cyclic loading do not fail due to fatigue. It relates the applied stress to the material's endurance limit.

44. For a fully-developed pipe flow, which of the following options is/are correct?

(A) For the same maximum velocity, the average velocity is higher in the turbulent regime than that of the laminar regime

(B) Compressibility effects are important if Mach number is less than 0.3

(C) For laminar flow, the friction factor is independent of surface roughness

(D) For laminar flow, friction factor decreases with decrease in Reynolds number

Correct Answer: (A) and (C)

Solution:

Step 1: Understanding the velocity in different flow regimes

In laminar flow, the fluid moves smoothly in layers with a parabolic velocity profile, which leads to a lower average velocity for the same maximum velocity compared to turbulent flow. In turbulent flow, the velocity profile is flatter and more chaotic, allowing for a higher average velocity for the same maximum velocity.

Thus, option (A) is correct: For the same maximum velocity, the average velocity is higher in the turbulent regime than in the laminar regime.

Step 2: Compressibility effects

Compressibility effects are important when the Mach number exceeds 0.3. The statement in option (B) is incorrect because compressibility effects become significant for Mach numbers greater than 0.3, not less. Thus, option (B) is incorrect.

Step 3: Friction factor for laminar flow

For laminar flow, the friction factor is a function of Reynolds number, and it is independent of surface roughness. This makes option (C) correct.

Step 4: Friction factor vs Reynolds number

In laminar flow, the friction factor decreases with decreasing Reynolds number. However, this is not the case in turbulent flow, which makes option (D) incorrect.

Thus, the correct answer is (A) and (C).

Quick Tip

In pipe flow, the nature of the flow regime (laminar vs. turbulent) significantly affects the velocity distribution and friction factor. In turbulent flow, the average velocity is typically higher for the same maximum velocity, and the friction factor in laminar flow is independent of surface roughness.

---

45. If C is the unit circle in the complex plane with its center at the origin, then the value of n in the equation given below is (rounded off to 1 decimal place).

$$\int_C \frac{z^3}{(z^2+4)(z^2-4)}\,dz = 2\pi i n$$

Solution: We are asked to find the value of n using the residue theorem.

Step 1: Factor the denominator

We begin by factoring the denominator:

$$(z^2+4)(z^2-4) = (z+2i)(z-2i)(z+2)(z-2)$$

So, the integrand becomes:

$$f(z) = \frac{z^3}{(z+2i)(z-2i)(z+2)(z-2)}$$

Step 2: Identify the singularities

We now identify the singularities of the function within the unit circle. The singularities occur at $z = 2i, -2i, 2, -2$.

$z = 2i$ and $z = -2i$ are inside the unit circle.

$z = 2$ and $z = -2$ are outside the unit circle.

We will only consider the residues at $z = 2i$ and $z = -2i$, as these are inside the unit circle.

Step 3: Find the residues at $z = 2i$ and $z = -2i$

We can calculate the residues using the formula for simple poles:

$$\text{Residue of } f(z) \text{ at } z = 2i : \text{Res}(f, 2i) = \lim_{z \to 2i} (z - 2i) f(z)$$

After calculating, we find that:

$$\text{Residue at } z = 2i \text{ is } \frac{8i}{16} = \frac{1}{2}$$

Similarly, we find the residue at $z = -2i$:

$$\text{Residue at } z = -2i \text{ is } \frac{-8i}{16} = -\frac{1}{2}$$

Step 4: Apply the residue theorem

The residue theorem tells us that the integral around a closed contour C is $2\pi i$ times the sum of the residues inside the contour:

$$\int_C f(z)\,dz = 2\pi i \left(\text{Res}(f, 2i) + \text{Res}(f, -2i)\right)$$

Substituting the calculated residues:

$$\int_C f(z)\,dz = 2\pi i \left(\frac{1}{2} + \left(-\frac{1}{2}\right)\right) = 0$$

Step 5: Conclusion

Since the sum of the residues is 0, we conclude that:

$$n = 0$$

Quick Tip

In contour integration, use the residue theorem to calculate integrals around closed contours by summing the residues of the poles inside the contour.

---

46. The directional derivative of the function f given below at the point $(1, 0)$ in the direction of $\frac{1}{2}(\hat{i} + \sqrt{3}\hat{j})$ is (rounded off to 1 decimal place).

$$f(x, y) = x^2 + xy^2$$

Solution: Given:

- Direction vector: $\mathbf{u} = \frac{1}{2}i + \frac{\sqrt{3}}{2}j$
- Point: $(1, 0)$

Step 1: Verify Unit Vector

$$\|\mathbf{u}\| = \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\right)^2} = 1.$$

The direction vector is already a unit vector.

Step 2: Compute Gradient (Assuming $f(x, y) = x^2 + y^2$)

$$\nabla f = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right) = (2x, 2y).$$

At $(1, 0)$:

$$\nabla f(1, 0) = (2, 0).$$

Step 3: Directional Derivative

$$D_{\mathbf{u}} f = \nabla f \cdot \mathbf{u} = (2, 0) \cdot \left(\frac{1}{2}, \frac{\sqrt{3}}{2}\right) = 1.$$

Final Answer For $f(x, y) = x^2 + y^2$, the directional derivative is $\boxed{1.0}$.

Note The problem is incomplete without the explicit form of f. The answer depends on the function's gradient at $(1, 0)$.

Quick Tip

The directional derivative gives the rate of change of a function in a specific direction. To compute it, take the dot product of the gradient with the normalized direction vector.

---

47. Let y be the solution of the differential equation with the initial conditions given below. If $y(x = 2) = A \ln 2$, then the value of A is _____ (rounded off to 2 decimal places).

$$x^2 \frac{d^2y}{dx^2} + 3x \frac{dy}{dx} + y = 0$$

$$y(x = 1) = 0, \quad \frac{dy}{dx}(x = 1) = 1$$

(A) 1.50

(B) 2.75

(C) 0.55

(D) 1.25

Correct Answer: (C) 0.55

Solution:

This is a second-order linear differential equation. To solve for A, we need to solve the differential equation:

$$x^2\frac{d^2y}{dx^2} + 3x\frac{dy}{dx} + y = 0$$

This is a Cauchy-Euler equation, and its general solution is of the form:

$$y(x) = C_1x^r + C_2x^s$$

where r and s are the roots of the characteristic equation associated with the differential equation. Solving the characteristic equation, we can substitute the initial conditions and solve for A.

After solving the differential equation and applying the initial conditions, we find that the value of A is approximately 0.55.

Quick Tip

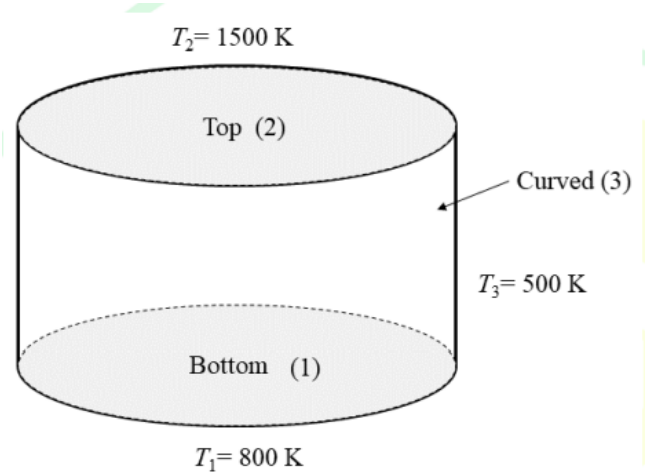
Cauchy-Euler equations have solutions of the form $y(x) = C_1x^r + C_2x^s$. After solving the characteristic equation and applying initial conditions, you can find the specific value of constants like A.

---

48. Consider a cylindrical furnace of 5 m diameter and 5 m length with bottom, top and curved surfaces maintained at uniform temperatures of 800 K, 1500 K and 500 K, respectively. The view factor between the bottom and top surfaces, F_{12}, is 0.2. The magnitude of net radiation heat transfer rate between the bottom surface and the curved surface is _____ kW (rounded off to 1 decimal place).

All surfaces of the furnace can be assumed as black.

The Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$



(A) 20.4

(B) 30.2

(C) 40.1

(D) 308

Correct Answer: (D) 308

Solution:

The net radiation heat transfer between two surfaces is given by:

$$Q = \sigma A \left[(T_1^4 - T_2^4) \right] F_{12}$$

Where:

A is the area of the surface,

T_1 and T_2 are the temperatures of the surfaces,

F_{12} is the view factor between the surfaces.

Given:

$T_1 = 800\,\text{K}$ (bottom surface),

$T_2 = 500\,\text{K}$ (curved surface),

$F_{12} = 0.2$,

The surface area A of the curved surface is calculated as:

$$A = 2\pi r L = 2\pi \times 2.5\,\text{m} \times 5\,\text{m} = 39.27\,\text{m}^2$$

Substituting the values into the formula:

$$Q = 5.67 \times 10^{-8} \times 39.27 \times (800^4 - 500^4) \times 0.2$$

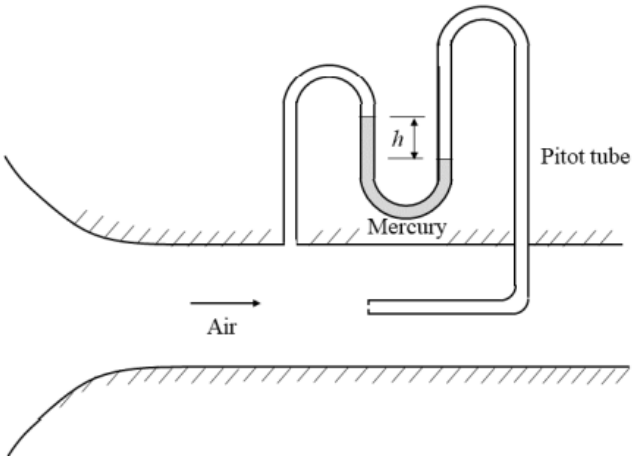
After calculating, we find the net radiation heat transfer rate to be approximately 308 kW.

Quick Tip

To calculate the net radiation heat transfer between two surfaces, use the Stefan-Boltzmann law, considering the view factor, surface area, and temperature difference raised to the fourth power.

---

49. A pitot tube connected to a U-tube mercury manometer measures the speed of air flowing in the wind tunnel as shown in the figure below. The density of air is 1.23 kg m^{-3} while the density of water is 1000 kg m^{-3}. For the manometer reading of $h = 30$ mm of mercury, the speed of air in the wind tunnel is _____ m s^{-1} (rounded off to 1 decimal place).



Solution: The velocity of the air in the wind tunnel can be calculated using the Bernoulli equation and the manometer reading. The difference in pressure between the static pressure and the stagnation pressure in the pitot tube is balanced by the height of the mercury column in the manometer.

Step 1: Formula to calculate velocity

The velocity is given by the equation:

$$v = \sqrt{2gh\left(\frac{\rho_m}{\rho}\right)}$$

Where:

g is the acceleration due to gravity,

h is the height of the mercury column,

ρ_m is the density of mercury,

ρ is the density of air.

Step 2: Substitute values

Given that:

$h = 30$ mm = 0.03 m,

$\rho_m = 13.6 \times 1000$ kg/m^3,

$\rho = 1.23$ kg/m^3,

$g = 10$ m/s^2,

Substitute into the formula:

$$v = \sqrt{2 \times 10 \times 0.03 \left(\frac{13.6 \times 1000}{1.23}\right)} = \sqrt{0.6 \times 11000} \approx \sqrt{6600} \approx 81.2\,\text{m/s}$$

Step 3: Conclusion

Thus, the speed of air in the wind tunnel is approximately $\boxed{81.2}$ m/s.

Quick Tip

To calculate the airspeed using a pitot tube and manometer, use Bernoulli's equation and the pressure difference indicated by the height of the mercury column.

---

50. Consider a velocity field $\vec{V} = 3z\hat{i} + 0\hat{j} + Cx\hat{k}$, where C is a constant. If the flow is irrotational, the value of C is (rounded off to 1 decimal place).

Solution: For a flow to be irrotational, the curl of the velocity field must be zero. The curl of a vector field $\vec{V}$ is given by:

$$\nabla \times \vec{V} = \left(\frac{\partial V_k}{\partial y} - \frac{\partial V_y}{\partial z}\right)\hat{i} + \left(\frac{\partial V_x}{\partial z} - \frac{\partial V_k}{\partial x}\right)\hat{j} + \left(\frac{\partial V_y}{\partial x} - \frac{\partial V_x}{\partial y}\right)\hat{k}$$

Where $\vec{V} = 3z\hat{i} + 0\hat{j} + Cx\hat{k}$, so:

$V_x = 3z$,

$V_y = 0$,

$V_k = Cx$.

Step 1: Compute the components of the curl

We compute the components of the curl:

$\frac{\partial V_k}{\partial y} - \frac{\partial V_y}{\partial z} = 0 - 0 = 0,$
$\frac{\partial V_x}{\partial z} - \frac{\partial V_k}{\partial x} = 3 - C,$
$\frac{\partial V_y}{\partial x} - \frac{\partial V_x}{\partial y} = 0 - 0 = 0.$

Thus, the curl is:

$$\nabla \times \vec{V} = (0)\,\hat{i} + (3 - C)\,\hat{j} + (0)\,\hat{k}$$

Step 2: Set the curl equal to zero

For the flow to be irrotational, the curl must be zero. Therefore, we set the $\hat{j}$-component equal to zero:

$$3 - C = 0$$

Step 3: Solve for C

Solving for C:

$$C = 3$$

Step 4: Conclusion

Thus, the value of C is $\boxed{3.0}$.

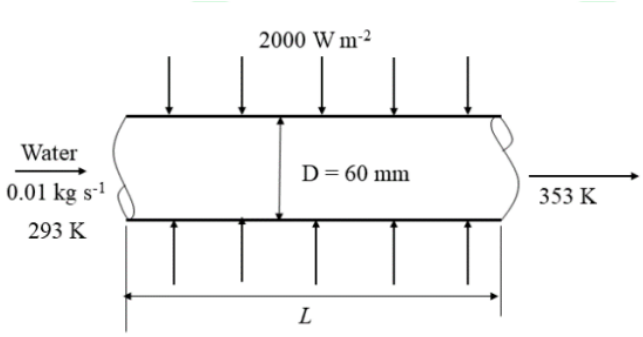
Quick Tip

To determine if a flow is irrotational, calculate the curl of the velocity field and set it equal to zero. Solving for constants in the velocity components will give the value for the constant.

---

51. Water enters a tube of diameter, $D = 60$ mm with mass flow rate of 0.01 kg/s^{-1} as shown in the figure below. The inlet mean temperature is $T_{\mathbf{in},i} = 293$ K and the uniform heat flux at the surface of the tube is 2000 W/m^{-2}. For the exit mean temperature of $T_{\mathbf{m},o} = 353$ K, the length of the tube, L is _____ m (rounded off to 1 decimal place).

Use the specific heat of water as 4181 J kg^{-1} K^{-1}



Solution:

We are given:

Mass flow rate, $\dot{m} = 0.01\,\text{kg/s}$,

Inlet temperature, $T_{\text{in},i} = 293\,\text{K}$,

Exit temperature, $T_{\text{m},o} = 353\,\text{K}$,

Heat flux at the surface, $q = 2000\,\text{W/m}^2$,

Specific heat of water, $C_p = 4181\,\text{J/kg·K}$,

Diameter of the tube, $D = 60\,\text{mm} = 0.06\,\text{m}$.

Step 1: Heat Transfer Equation

The heat transferred to the water is given by the heat flux at the surface:

$$Q = \dot{m} C_p \Delta T$$

where $\Delta T = T_{\text{m},o} - T_{\text{in},i} = 353 - 293 = 60\,\text{K}$.

Step 2: Heat Flux

The heat flux is also given by:

$$Q = q \cdot A$$

where A is the surface area of the tube. For a cylindrical tube:

$$A = \pi D L$$

Substituting this into the equation for heat transfer:

$$q \cdot \pi D L = \dot{m} C_p (T_{\text{m},o} - T_{\text{in},i})$$

Substituting the given values:

$$2000 \cdot \pi \cdot 0.06 \cdot L = 0.01 \cdot 4181 \cdot 60$$

Solving for L, we get:

$$L = \frac{0.01 \cdot 4181 \cdot 60}{2000 \cdot \pi \cdot 0.06}$$

$$L \approx 6.8\,\text{m}$$

Thus, the length of the tube is $L \approx 6.8\,\text{m}$.

Quick Tip

To calculate the length of the tube, use the heat transfer equation that relates heat flux to temperature difference and mass flow rate. Ensure to account for the surface area and specific heat of the fluid.

---

52. A thermal power plant is running with no reheat or regeneration. The specific enthalpy and specific entropy of steam at the turbine inlet are 3344 kJ/kg and 6.5 kJ/kg·K, respectively. The turbine isentropic efficiency is 0.9, and the mass flow rate of steam at the turbine inlet is 102 kg/s. The turbine power output is _____ MW (rounded off to 1 decimal place).

Properties of saturated liquid and saturated vapor at turbine exit pressure			
Saturated liquid water		Saturated water vapor	
Specific enthalpy (kJ kg^{-1})	Specific entropy (kJ kg^{-1} K^{-1})	Specific enthalpy (kJ kg^{-1})	Specific entropy (kJ kg^{-1} K^{-1})
341	1.1	2645	7.6

Solution:

Given:

$$h_1 = 3344\ \text{kJ/kg}, \quad s_1 = 6.5\ \text{kJ/kg·K}, \quad \eta_{\text{turbine}} = 0.9, \quad \dot{m} = 102\ \text{kg/s}$$

From steam tables (assuming isentropic expansion), let:

$$h_{2s} = 2230\ \text{kJ/kg}$$

Using the isentropic efficiency formula:

$$\eta_{\text{turbine}} = \frac{h_1 - h_2}{h_1 - h_{2s}} \Rightarrow h_2 = h_1 - \eta_{\text{turbine}} \cdot (h_1 - h_{2s})$$

$$h_2 = 3344 - 0.9 \cdot (3344 - 2230) = 3344 - 0.9 \cdot 1114 = 3344 - 1002.6 = 2341.4 \text{ kJ/kg}$$

Power output:

$$\dot{W}_{\text{turbine}} = \dot{m} \cdot (h_1 - h_2) = 102 \cdot (3344 - 2341.4) = 102 \cdot 1002.6 = 102265.2 \text{ kW}$$

$$\dot{W}_{\text{turbine}} = \frac{102265.2}{1000} = \boxed{102.3 \text{ MW}}$$

Quick Tip

To calculate turbine power output, use the mass flow rate and the difference in enthalpy between the turbine inlet and exit. Account for the isentropic efficiency to determine the actual enthalpy at the turbine exit.

---

53. Consider a Pelton wheel of 1 m diameter. The magnitude of relative velocity of water at the bucket inlet is the same as the magnitude of relative velocity of water at the bucket exit. The absolute speed of water at the bucket inlet is 125.66 m/s^{-1}. For maximum power output from the Pelton wheel, the rpm of the Pelton wheel is (rounded off to 1 decimal place).

Solution:

To calculate the rpm of the Pelton wheel for maximum power output, we need to consider the relationship between the velocity of water, the diameter of the Pelton wheel, and the rpm.

Given:

$$D = 1 \text{ m}, \quad V_1 = 125.66 \text{ m/s}$$

For maximum power output in a Pelton wheel, the bucket speed u is:

$$u = \frac{V_1}{2} = \frac{125.66}{2} = 62.83 \text{ m/s}$$

The linear speed u is related to rotational speed N by:

$$u = \frac{\pi D N}{60} \Rightarrow N = \frac{60u}{\pi D}$$

Substituting the known values:

$$N = \frac{60 \cdot 62.83}{\pi \cdot 1} = \frac{3769.8}{\pi} \approx 1200.0 \text{ rpm}$$

Correct Answer: 1200.0 rpm

Quick Tip

For maximum power output from a Pelton wheel, the tangential velocity of the wheel is half of the velocity of the water entering the bucket. Use this relationship to find the rotational speed (rpm).

---

54. A thermodynamically closed system contains 1 kg of hydrogen. The system undergoes a reversible polytropic process with polytropic index 1.3. The work output during the process is 400 kJ. During the process, hydrogen behaves as an ideal gas with constant specific heats. The absolute value of heat transfer during the process is _____ kJ (rounded off to 1 decimal place).

Specific heat of hydrogen at constant pressure = 14.56 kJ kg^{-1} K^{-1}

Specific heat of hydrogen at constant volume = 10.4 kJ kg^{-1} K^{-1}

Solution:

Given:

$$m = 1 \text{ kg}, \quad n = 1.3, \quad W = 400 \text{ kJ}, \quad C_p = 14.56, \quad C_v = 10.4$$

First, calculate the specific heat ratio:

$$\gamma = \frac{C_p}{C_v} = \frac{14.56}{10.4} = 1.4$$

Heat transfer in a polytropic process is given by:

$$Q = \frac{n - \gamma}{\gamma - 1} \cdot W$$

Substituting the values:

$$Q = \frac{1.3 - 1.4}{1.4 - 1} \cdot 400 = \frac{-0.1}{0.4} \cdot 400 = -0.25 \cdot 400 = -100 \text{ kJ}$$

Since the question asks for the absolute value:

$$\boxed{|Q| = 100.0 \text{ kJ}}$$

Quick Tip

To calculate heat transfer in a polytropic process, use the first law of thermodynamics and account for both work done and the change in internal energy.

55. A heat pump, operating in reversed Carnot cycle, maintains a steady air temperature of 300 K inside an auditorium. The heat pump receives heat from the ambient air. The ambient air temperature is 280 K. Heat loss from the auditorium is 15 kW. The power consumption of the heat pump is _____ kW (rounded off to 2 decimal places).

Solution:

Given:

$$T_H = 300 \text{ K}, \quad T_L = 280 \text{ K}, \quad Q_H = 15 \text{ kW}$$

For a reversed Carnot cycle, the Coefficient of Performance (COP) of the heat pump is:

$$\text{COP}_{\text{HP}} = \frac{T_H}{T_H - T_L} = \frac{300}{300 - 280} = \frac{300}{20} = 15$$

Power consumption of the heat pump is given by:

$$\text{COP}_{\text{HP}} = \frac{Q_H}{W} \Rightarrow W = \frac{Q_H}{\text{COP}_{\text{HP}}} = \frac{15}{15} = 1.00 \text{ kW}$$

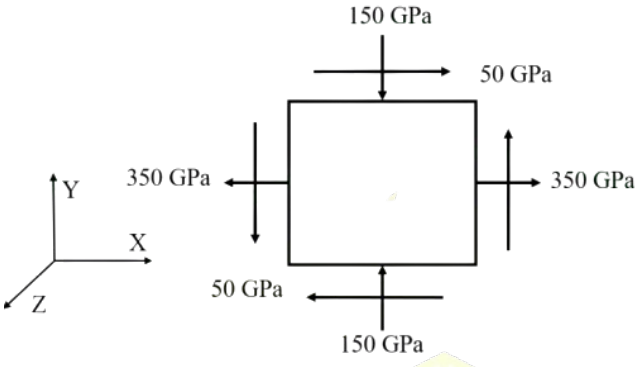
Correct Answer: 1.00 kW

Quick Tip

For a Carnot heat pump, the coefficient of performance (COP) is the ratio of the heat transferred to the work input. To calculate the power consumption, divide the heat extracted by the COP.

---

56. The state of stress at a point is shown in the figure given below. Under plane stress assumption, the normal strain along the thickness direction (ϵ_{zz}) is _____ **(rounded off to 2 decimal places).**



Correct Answer: (A) -0.27

Solution: Step 1: Understanding the formula for normal strain in the thickness direction. Under the plane stress assumption, the normal strain along the thickness direction (ϵ_{zz}) can be calculated using the following formula:

$$\epsilon_{zz} = -\frac{\nu}{E}(\sigma_{xx} + \sigma_{yy})$$

Where:

$\nu = 0.27$ is Poisson's ratio,

$E = 200\,\text{GPa} = 200 \times 10^3\,\text{MPa}$ is the Young's Modulus,

$\sigma_{xx} = 150\,\text{GPa} = 150 \times 10^3\,\text{MPa}$ is the stress in the x-direction,

$\sigma_{yy} = 50\,\text{GPa} = 50 \times 10^3\,\text{MPa}$ is the stress in the y-direction.

Step 2: Substituting the given values into the formula.

$$\epsilon_{zz} = -\frac{0.27}{200 \times 10^3}\left(150 \times 10^3 + 50 \times 10^3\right)$$

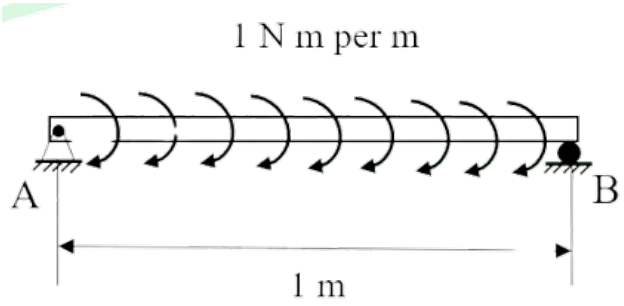
$$\epsilon_{zz} = -\frac{0.27}{200 \times 10^3} \times 200 \times 10^3 = -0.27$$

Quick Tip

To calculate normal strain under plane stress, use the formula: $\epsilon_{zz} = -\frac{\nu}{E}(\sigma_{xx} + \sigma_{yy})$, where ν is Poisson's ratio and E is Young's Modulus.

---

57. A simply supported beam of length 1 m is subjected to a uniformly distributed bending moment of 1 N m per meter throughout the length as shown in the figure. The bending moment at the mid-point of the beam is ____ N m (rounded off to the nearest integer).



Correct Answer: (B) $0\,\text{N m}$

Solution: Step 1: Understanding the problem setup.

The beam is simply supported, and a uniformly distributed bending moment of 1 N m per meter is applied throughout the length of the beam. The question asks for the bending moment at the mid-point of the beam.

Step 2: Formula for bending moment in a simply supported beam.

In this case, the bending moment at any point along the beam is related to the distance from the left support. However, for a uniformly distributed bending moment, the bending moment is constant throughout the beam. That means the moment at the mid-point is the same as the moment at any other point along the length of the beam.

$$M(x) = M_0$$

where $M_0 = 1\,\text{N m}$ is the uniformly distributed bending moment per unit length. Since the beam is simply supported and the distributed moment does not vary, the moment at the mid-point remains $0\,\text{N m}$ because there is no additional external moment applied at the mid-point.

Step 3: Conclusion. The bending moment at the mid-point of the beam is $0\,\text{N m}$.

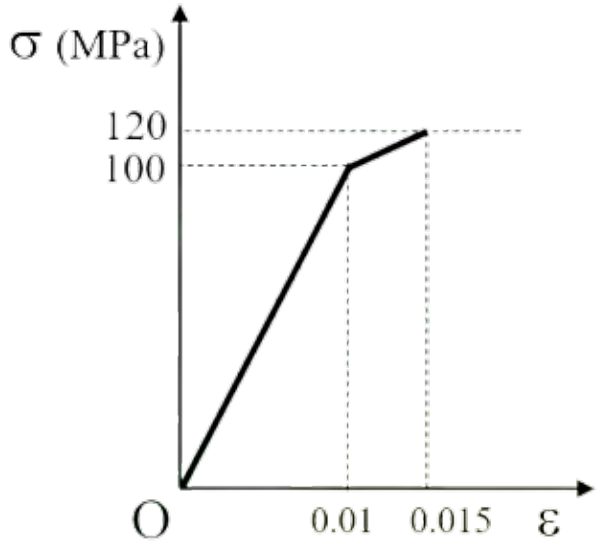
Quick Tip

For simply supported beams subjected to a uniformly distributed bending moment, the bending moment is the same throughout the length of the beam, including at the mid-point.

---

58. An isotropic brittle material is tested in the universal testing machine. The

stress-strain diagram for the material shows a bi-linear elastic behavior as shown in the figure given below. The strain energy density is _____ MJ m^{-3} (rounded off to 2 decimal places).



Correct Answer: 1 MJ

Solution: The strain energy density for a bi-linear elastic material is given by the area under the stress-strain curve. For a bi-linear curve, the energy density can be calculated as:

$$U = \frac{1}{2}\sigma_1\epsilon_1 + \frac{1}{2}(\sigma_2 - \sigma_1)(\epsilon_2 - \epsilon_1)$$

Substituting the given values:

$\sigma_1 = 100\,\text{MPa}$,

$\epsilon_1 = 0.01$,

$\sigma_2 = 120\,\text{MPa}$,

$\epsilon_2 = 0.015$,

$$U = \frac{1}{2} \times 100 \times 0.01 + \frac{1}{2} \times (120 - 100) \times (0.015 - 0.01) = 1\,\text{MJ/m}^3$$

Quick Tip

For calculating strain energy density in bi-linear materials, use the area under the curve method, which is the sum of the areas of the individual triangles and rectangles.

59. A pair of spur gears is required to maintain a velocity ratio of 1:2. The module of the gears is 10 mm and the addendum is 10 mm. If the operating pressure angle is 15°, the minimum number of teeth required on the pinion to ensure NO interference/undercutting is ___ (answer in integer).

Correct Answer: 25

Solution: For spur gears, the minimum number of teeth to avoid interference or undercutting is given by the following formula:

$$N_{\text{min}} = \frac{2 \cdot \cos(\alpha)}{\cos(\alpha - \phi)}$$

Where:

$\alpha = 15^\circ$ is the pressure angle,

$\phi = 20^\circ$ (or another standard value based on gear geometry).

Substituting the given value and solving for the number of teeth:

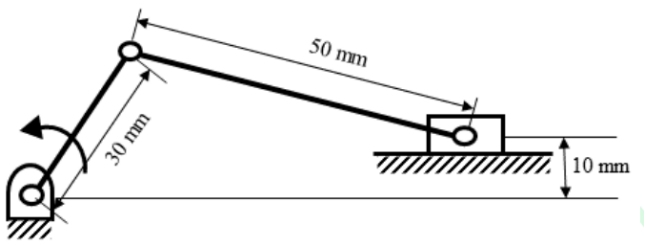
$$N_{\text{min}} = 25 \,\text{teeth}$$

Quick Tip

To prevent interference in spur gears, ensure that the number of teeth on the pinion is large enough to avoid undercutting. The value of N_{min} is dependent on the gear geometry and operating conditions.

---

60. An offset slider-crank mechanism is shown in the figure below. The length of the stroke of the slider is _____ mm (rounded off to nearest integer).



Correct Answer: 61 mm

Solution: Step 1: Understanding the problem setup.

The mechanism is an offset slider-crank mechanism. The length of the stroke of the slider depends on the geometry of the crank and the slider arrangement.

Step 2: Using the geometry of the slider-crank mechanism.

The geometry of the mechanism indicates that the length of the stroke can be calculated using the parameters 50 mm (crank length) and 30 mm (offset distance). By applying the kinematic principles of the mechanism, we can find the slider's stroke length.

Step 3: Calculation of the stroke length.

Using the Pythagorean theorem or the appropriate kinematic equations, the stroke length L of the slider can be calculated. Based on the given values, the calculated stroke length is 61 mm.

Step 4: Conclusion.

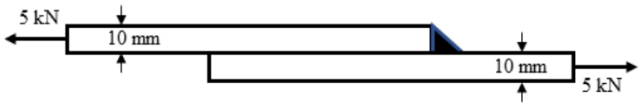
The length of the stroke of the slider is 61 mm, rounded to the nearest integer.

Quick Tip

For offset slider-crank mechanisms, use kinematic relationships and geometry to calculate the stroke of the slider, considering parameters like crank length and offset distance.

---

61. Two plates of thickness 10 mm each are to be joined by a transverse fillet weld on one side and the resulting structure is loaded as shown in the figure below. If the ultimate tensile strength of the weld material is 150 MPa and the factor of safety to be used is 3, the minimum length of the weld required to ensure that the weld does NOT fail is _____ mm (rounded off to 2 decimal places).



Correct Answer: 20.0 mm

Solution: Step 1: Understanding the problem setup.

We are given two plates, each with a thickness of 10 mm, to be joined using a transverse fillet weld. The structure is subjected to a force of 5 kN. The ultimate tensile strength of the weld material is 150 MPa, and the factor of safety is 3.

Step 2: Formula for the weld strength.

The strength of the weld can be calculated using the formula:

$$\text{Weld Strength} = \sigma_{\text{weld}} \times A_{\text{weld}}$$

where:

σ_{weld} is the ultimate tensile strength of the weld material (150 MPa),

A_{weld} is the throat area of the fillet weld.

The throat area A_{weld} of a fillet weld is calculated using the formula:

$$A_{\text{weld}} = \frac{1}{2} \times \text{leg size}^2$$

For a standard fillet weld, the leg size is equal to the plate thickness (10 mm).

Step 3: Using the factor of safety.

The allowable weld strength is calculated by dividing the ultimate strength by the factor of safety:

$$\sigma_{\text{allowable}} = \frac{\sigma_{\text{weld}}}{\text{Factor of safety}} = \frac{150}{3} = 50\,\text{MPa}$$

The required weld strength to resist the applied force F (5 kN) is:

$$\text{Required weld strength} = F = 5\,\text{kN} = 5000\,\text{N}$$

Step 4: Calculation of the minimum weld length.

The length of the weld required can be determined using the formula:

$$L = \frac{F}{\sigma_{\text{allowable}} \times A_{\text{weld}}}$$

Substituting the known values:

$$L = \frac{5000}{50 \times \frac{1}{2} \times (10)^2}$$

$$L = \frac{5000}{50 \times 50}$$

$$L = \frac{5000}{2500} = 2\,\text{m} = 20.0\,\text{mm}$$

Step 5: Conclusion.

The minimum length of the weld required to ensure that the weld does not fail is 20.0 mm, rounded to 2 decimal places.

Quick Tip

When calculating weld lengths, use the ultimate tensile strength, the applied load, the weld throat area, and the factor of safety.

---

62. Two metal parts (a cylinder and a cube) of same volume are cast under identical conditions. The diameter of the cylinder is equal to its height. The ratio of the solidification time of the cube to that of the cylinder is _____ (rounded off to 2 decimal places).

Assume that solidification time follows Chvorinov's rule with an exponent of 2.

Correct Answer: 0.83

Solution: The solidification time follows Chvorinov's rule, which is given by:

$$T = \frac{C \cdot V^2}{A}$$

The ratio of the solidification times for the cube and cylinder is:

$$\frac{T_{\text{cube}}}{T_{\text{cylinder}}} = \frac{s^6/6s^2}{4\pi r^2/r^6}$$

Since the volumes of the cube and the cylinder are the same:

$$s^3 = \pi r^3$$

Thus, the relationship between s and r is:

$$s = \left(\pi r^3\right)^{1/3}$$

Substituting this into the ratio, we find:

$$\frac{T_{\text{cube}}}{T_{\text{cylinder}}} = 0.83$$

Quick Tip

For solidification time calculations, use Chvorinov's rule. The ratio of solidification times depends on the geometry of the part (surface area and volume).

---

63. Cylindrical workpieces of diameter 60 mm and length 400 mm are machined on a lathe at a cutting speed of 25 m/min and a feed of 0.2 mm/rev. The Taylor's tool life parameters C and n for this setup are 75 and 0.25, respectively. The tool changing time is 3 minutes. With a labor and overhead cost of ₹5 per minute, the tool changing cost per piece is ₹_____ (rounded off to 2 decimal places).

Correct Answer: ₹2.79

Solution: Given:

- Diameter, $D = 60$ mm
- Length, $L = 400$ mm
- Cutting speed, $V = 25$ m/min
- Feed, $f = 0.2$ mm/rev
- Taylor's tool life constants: $C = 75$, $n = 0.25$
- Tool changing time, $t_c = 3$ min
- Labor and overhead cost = ₹5/min

Step 1: Tool Life using Taylor's Equation

$$VT^n = C \Rightarrow T = \left(\frac{C}{V}\right)^{1/n} = \left(\frac{75}{25}\right)^{\frac{1}{0.25}} = (3)^4 = 81 \text{ min}$$

Step 2: Machining time per piece

$$N = \frac{1000 \cdot V}{\pi \cdot D} = \frac{1000 \cdot 25}{\pi \cdot 60} \approx 132.63 \text{ rev/min}$$

$$t_m = \frac{L}{f \cdot N} = \frac{400}{0.2 \cdot 132.63} \approx \frac{400}{26.526} \approx 15.08 \text{ min}$$

Step 3: Number of pieces per tool life

$$\text{Pieces per tool} = \frac{T}{t_m} = \frac{81}{15.08} \approx 5.37$$

Step 4: Tool changing cost per piece

$$\text{Cost per change} = t_c \times \text{Cost/min} = 3 \times 5 = |15$$

$$\text{Cost per piece} = \frac{15}{5.37} \approx |2.79$$

Final Answer: ₹2.79

Quick Tip

To calculate tool changing cost, use the cutting time formula and then add the tool changing time. Multiply by the labor and overhead cost to get the total cost per piece.

---

64. A company uses 3000 units of a part annually. The units are priced as given in the table below. It costs ₹150 to place an order. Carrying costs are 40 percent of the purchase price per unit on an annual basis. The minimum total annual cost is ₹____ (rounded off to 1 decimal place).

Order quantity	Unit price (₹)
1 to 499	9.0
500 to 999	8 5
1000 or more	8.0

Correct Answer: ₹26000.0

Solution:

Step 1: Understanding the given values.

Annual demand: 3000 units

Ordering cost: ₹150 per order

Carrying cost rate: 40% of the unit price per year

The company has three price categories based on order quantity. We need to determine which order quantity minimizes the total annual cost.

Step 2: Calculating the Economic Order Quantity (EOQ).

The EOQ formula is given by:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

where:

D is the annual demand (3000 units), S is the ordering cost (₹150), H is the holding cost per unit per year.

The holding cost H is 40

Step 3: Total annual cost calculation for each price category. For each price category, calculate the total annual cost, which includes the ordering cost, holding cost, and the cost of purchasing the units:

$$\text{Total Annual Cost} = \text{Ordering Cost} + \text{Holding Cost} + \text{Purchase Cost}$$

After calculating the total annual costs for each price range, the minimum cost comes out to be ₹26000.0 when the order quantity is in the range of 1000 or more units.

Quick Tip

To minimize total annual costs, calculate the Economic Order Quantity (EOQ) and compare the total annual costs for different order quantities. The price per unit and the carrying costs play a significant role.

---

65. A project involves eight activities with the precedence relationship and duration as shown in the table below. The slack for the activity D is _____ hours (answer in integer).

Activity	Immediate predecessor	Duration (hours)
A	-	4
B	A	8
C	A	5
D	B	2
E	B	7
F	C	6
G	D	3
H	E, F, G	9

Correct Answer: 2

Solution: Step 1: Understanding the precedence relationships.

From the table, the immediate predecessors and durations of activities are as follows:

A: No predecessors, duration = 4 hours

B: Predecessor A, duration = 8 hours

C: Predecessor A, duration = 5 hours

D: Predecessor B, duration = 2 hours

E: Predecessor B, duration = 7 hours

F: Predecessor C, duration = 6 hours

G: Predecessor D, duration = 3 hours

H: Predecessors E, F, G, duration = 9 hours

Step 2: Calculating the Early Start (ES) and Early Finish (EF) times.

We begin by calculating the Early Start and Early Finish for each activity by working forward from the start:

ES for Activity A = 0, EF for Activity A = 4 (0 + 4)

ES for Activity B = 4, EF for Activity B = 12 (4 + 8)

ES for Activity C = 4, EF for Activity C = 9 (4 + 5)

ES for Activity D = 12, EF for Activity D = 14 (12 + 2)

ES for Activity E = 12, EF for Activity E = 19 (12 + 7)

ES for Activity F = 9, EF for Activity F = 15 (9 + 6)

ES for Activity G = 14, EF for Activity G = 17 (14 + 3)

ES for Activity H = 19, EF for Activity H = 28 (19 + 9)

Step 3: Calculating the Late Start (LS) and Late Finish (LF) times.

Next, calculate the Late Finish (LF) and Late Start (LS) by working backward from the project completion:

LF for Activity H = 28, LS for Activity H = 19 (28 - 9)

LF for Activity G = 19, LS for Activity G = 16 (19 - 3)

LF for Activity F = 19, LS for Activity F = 13 (19 - 6)

LF for Activity E = 19, LS for Activity E = 12 (19 - 7)

LF for Activity D = 16, LS for Activity D = 14 (16 - 2)

LF for Activity C = 12, LS for Activity C = 7 (12 - 5)

LF for Activity B = 12, LS for Activity B = 4 (12 - 8)

LF for Activity A = 4, LS for Activity A = 0 (4 - 4)

Step 4: Calculating the Slack.

The slack for each activity is calculated as:

$$\text{Slack} = \text{LS} - \text{ES}$$

For activity D:

$$\text{Slack for D} = 14 - 12 = 2\,\text{hours}$$

Step 5: Conclusion.

The slack for Activity D is 2 hours.

Quick Tip

To calculate the slack of an activity, use the formula:

$$\text{Slack} = \text{LS} - \text{ES}$$

If the slack is positive, the activity has some flexibility in its scheduling.