GATE 2026 Mechanical Engineering Question Paper with Solutions

Time Allowed :3 Hours	Maximum Marks :100	Total Questions :65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Each GATE 2024 paper consists of a total of 100 marks. The examination is divided into two sections – General Aptitude (GA) and the Candidate's Selected Subjects. General Aptitude carries 15 marks, while the remaining 85 marks are dedicated to the candidate's chosen test paper syllabus.
2. GATE 2024 will be conducted in English as a Computer Based Test (CBT) at select centres in select cities. The duration of the examination is 3 hours.
3. MCQs carry 1 mark or 2 marks.
4. For a wrong answer in a 1-mark MCQ, 1/3 mark is deducted.
5. For a wrong answer in a 2-mark MCQ, 2/3 mark is deducted.
6. No negative marking for wrong answers in MSQ or NAT questions.

1. Consider two infinitely long fins made of the same material and exposed to the same convective environment. One fin has a square cross-section of side a, and the other has a circular cross-section of diameter d. Assume $a = d$. The ratio of the steady-state heat transfer rate from the square fin to that from the circular fin, $\frac{\dot{Q}_{\text{square}}}{\dot{Q}_{\text{circular}}}$, is:

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

Correct Answer: (B) $\frac{4}{\pi}$

Solution:

Step 1: Understanding the Question:
We need to compare the heat transfer rates of two infinitely long fins: one with a square cross-section and one with a circular cross-section. The characteristic dimensions are equal (side a = diameter d). Both fins have the same thermal conductivity k and convective heat transfer coefficient h.
Step 2: Key Formula:
The rate of heat transfer from an infinitely long fin is given by:

$$\dot{Q} = \sqrt{hPkA_c}\,\theta_0$$

where:

- h = Convective heat transfer coefficient (constant for both)
- P = Perimeter of the cross-section
- k = Thermal conductivity (constant for both)
- A_c = Cross-sectional area
- θ_0 = Temperature difference at the base (constant for both)

Step 3: Calculation:
Since $h, k,$ and θ_0 are the same for both fins, the ratio depends only on the geometric parameters $\sqrt{PA_c}$.

$$\frac{\dot{Q}_{\text{square}}}{\dot{Q}_{\text{circular}}} = \frac{\sqrt{P_s A_{cs}}}{\sqrt{P_c A_{cc}}}$$

For the Square Fin (Side a): Perimeter $P_s = 4a$
Area $A_{cs} = a^2$
Geometric factor:

$$P_s A_{cs} = (4a)(a^2) = 4a^3$$

For the Circular Fin (Diameter $d = a$): Perimeter $P_c = \pi d = \pi a$
Area $A_{cc} = \frac{\pi}{4} d^2 = \frac{\pi}{4} a^2$
Geometric factor:

$$P_c A_{cc} = (\pi a)\left(\frac{\pi}{4} a^2\right) = \frac{\pi^2}{4} a^3$$

Taking the Ratio:

$$\text{Ratio} = \sqrt{\frac{4a^3}{\frac{\pi^2}{4} a^3}} = \sqrt{\frac{16}{\pi^2}} = \frac{4}{\pi}$$

Step 4: Final Answer:
The ratio is $\frac{4}{\pi}$.

Quick Tip

For fin comparison problems, identify the constant parameters first. If only the shape changes, $\dot{Q} \propto \sqrt{PA_c}$ for infinite fins, and $\dot{Q} \propto \sqrt{PA_c} \tanh(mL)$ for finite fins with insulated tips.

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2. A cantilever beam of length L is fixed at the left end ($x = 0$). It is subjected to a concentrated downward point load P and a concentrated clockwise moment $M = \frac{PL}{2}$ at the midpoint ($x = L/2$). Which of the following descriptions correctly represents the Shear Force Diagram (SFD) for the beam?

(A) A rectangular block of constant positive height P from $x = 0$ to $x = L/2$, and zero shear force from $x = L/2$ to $x = L$.
(B) A rectangular block of constant positive height P from $x = 0$ to $x = L/2$, followed by another rectangular block of height $P/2$ from $x = L/2$ to $x = L$.

(C) A triangular shape increasing linearly from $x = 0$ to $x = L/2$.
(D) A rectangular block from $x = 0$ to $x = L$, unaffected by the point load.

Correct Answer: (A) A rectangular block of constant positive height P from $x = 0$ to $x = L/2$, and zero shear force from $x = L/2$ to $x = L$.

Solution:

Step 1: Understanding the Question:
We need to determine the Shear Force Diagram (SFD) for a cantilever beam with a point load and a couple (moment) applied at the midpoint.
Step 2: Analyzing the Loads and Reactions:

- **Support:** Fixed at the left end ($x = 0$).
- **Loads at $x = L/2$:** Point load P (downward), Moment M (clockwise).
- **Reaction at Support ($x = 0$):** From vertical force equilibrium $\Sigma F_y = 0$:

$$R_A - P = 0 \Rightarrow R_A = P \, (\text{upwards})$$

Step 3: Constructing the SFD: Shear Force $V(x)$ is the sum of vertical forces to the left (or right) of the section.

- **Region $0 < x < L/2$:** Looking to the left, the only force is the support reaction $R_A = P$ (upwards).
$$V(x) = +P$$
The diagram is a horizontal line (rectangle).
- **At $x = L/2$:** There is a downward point load P. The shear force drops by P.
- **Region $L/2 < x < L$:**
$$V(x) = +P(\text{Reaction}) - P(\text{Load}) = 0$$
The shear force is zero in this section.

Step 4: Effect of the Moment M: A concentrated moment affects the Bending Moment Diagram (BMD) by creating a vertical jump, but it **does not** affect the Shear Force Diagram directly. Therefore, the moment at $L/2$ causes no change in the SFD shape.
Step 5: Conclusion: The SFD consists of a rectangle of magnitude P from the fixed end to the midpoint, and zero thereafter.

Quick Tip

Concentrated moments do not appear in the Shear Force Diagram (SFD); they only cause sudden jumps in the Bending Moment Diagram (BMD). Only vertical forces (point loads or distributed loads) affect the SFD.

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3. A vibrating system has a critical damping coefficient $C_c = 350\,\mathbf{N \cdot s/m}$ and an actual damping coefficient $C = 35\,\mathbf{N \cdot s/m}$. The logarithmic decrement of the system is approximately:

(A) 0.10
(B) 0.31
(C) 0.63
(D) 3.14

Correct Answer: (C) 0.63

Solution:

Step 1: Understanding the Question:
We are asked to calculate the logarithmic decrement (δ) given the actual damping coefficient (C) and the critical damping coefficient (C_c).
Step 2: Key Formulas:
1. Damping Ratio (ζ):

$$\zeta = \frac{C}{C_c}$$

2. Logarithmic Decrement (δ):

$$\delta = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$

Step 3: Calculation:
Calculate the damping ratio:

$$\zeta = \frac{35}{350} = 0.1$$

Calculate the logarithmic decrement:

$$\delta = \frac{2\pi(0.1)}{\sqrt{1-(0.1)^2}}$$

$$\delta = \frac{0.6283}{\sqrt{1-0.01}}$$

$$\delta = \frac{0.6283}{\sqrt{0.99}}$$

$$\delta = \frac{0.6283}{0.99498}$$

$$\delta \approx 0.631$$

Alternatively, for small damping ($\zeta < 0.1$), we can approximate $\delta \approx 2\pi\zeta$:

$$\delta \approx 2 \times 3.1416 \times 0.1 = 0.628$$

Both methods yield approximately 0.63.
Step 4: Final Answer:
The logarithmic decrement is 0.63.

Quick Tip

For small damping ratios ($\zeta < 0.1$), the logarithmic decrement can be quickly estimated using $\delta \approx 2\pi\zeta$. The error in this approximation is negligible for calculation-heavy exams.

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4. 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: 0.85

Solution:

Step 1: Understanding the Question:
We need to find the ratio of the solidification time of a cube to that of a cylinder, given they have the same volume and are cast under identical conditions. The cylinder's diameter is equal to its height. We must use Chvorinov's rule.

Step 2: Key Formula or Approach:
Chvorinov's rule states that the solidification time (t_s) is proportional to the square of the ratio of the volume (V) to the surface area (A) of the casting.

$$t_s = C\left(\frac{V}{A}\right)^n$$

Given that the exponent $n = 2$ and the casting conditions are identical (so the mold constant C is the same for both), the formula is:

$$t_s = C\left(\frac{V}{A}\right)^2$$

The ratio of solidification times is:

$$\frac{t_{\text{cube}}}{t_{\text{cylinder}}} = \frac{C(V_{\text{cube}}/A_{\text{cube}})^2}{C(V_{\text{cylinder}}/A_{\text{cylinder}})^2}$$

Since the volumes are the same ($V_{\text{cube}} = V_{\text{cylinder}}$), the equation simplifies to:

$$\frac{t_{\text{cube}}}{t_{\text{cylinder}}} = \left(\frac{A_{\text{cylinder}}}{A_{\text{cube}}}\right)^2$$

Step 3: Detailed Explanation:
Let the side of the cube be a.

- Volume of cube: $V_{\text{cube}} = a^3$
- Surface area of cube: $A_{\text{cube}} = 6a^2$

Let the height of the cylinder be h and its diameter be d. Given $d = h$, so the radius $r = d/2 = h/2$.

- Volume of cylinder: $V_{\text{cylinder}} = \pi r^2 h = \pi \left(\frac{h}{2}\right)^2 h = \frac{\pi h^3}{4}$
- Surface area of cylinder: $A_{\text{cylinder}} = 2\pi r^2(\text{top/bottom}) + 2\pi r h(\text{side}) = 2\pi \left(\frac{h}{2}\right)^2 + 2\pi \left(\frac{h}{2}\right) h = \frac{\pi h^2}{2} + \pi h^2 = \frac{3\pi h^2}{2}$

Now, we equate the volumes to find a relationship between a and h:

$$a^3 = \frac{\pi h^3}{4} \implies a = h \left(\frac{\pi}{4}\right)^{1/3}$$

Now we can express A_{cube} in terms of h:

$$A_{\text{cube}} = 6a^2 = 6\left(h\left(\frac{\pi}{4}\right)^{1/3}\right)^2 = 6h^2\left(\frac{\pi}{4}\right)^{2/3}$$

Now we find the ratio of the areas:

$$\frac{A_{\text{cylinder}}}{A_{\text{cube}}} = \frac{\frac{3\pi h^2}{2}}{6h^2\left(\frac{\pi}{4}\right)^{2/3}} = \frac{3\pi}{12}\frac{1}{(\pi/4)^{2/3}} = \frac{\pi}{4}(\pi/4)^{-2/3} = \left(\frac{\pi}{4}\right)^{1-2/3} = \left(\frac{\pi}{4}\right)^{1/3}$$

Finally, we calculate the ratio of solidification times:

$$\frac{t_{\text{cube}}}{t_{\text{cylinder}}} = \left(\frac{A_{\text{cylinder}}}{A_{\text{cube}}}\right)^2 = \left(\left(\frac{\pi}{4}\right)^{1/3}\right)^2 = \left(\frac{\pi}{4}\right)^{2/3}$$

$$\frac{t_{\text{cube}}}{t_{\text{cylinder}}} \approx (0.7854)^{2/3} \approx 0.8533$$

Rounding off to 2 decimal places, the ratio is 0.85.

Step 4: Final Answer:
The ratio of the solidification time of the cube to that of the cylinder is 0.85.

Quick Tip

For problems involving Chvorinov's rule, remember that for a given volume, a sphere has the minimum surface area and will therefore take the longest to solidify. A shape with a higher surface area-to-volume ratio will cool and solidify faster.

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5. 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) NOT feasible and 6.0
(B) NOT feasible and 2.6
(C) feasible and 3.6
(D) feasible and 3.0

Correct Answer: (C) feasible and 3.6

Solution:

Step 1: Understanding the Question:
We need to determine if a given rolling operation is feasible and calculate the maximum possible draft. The feasibility depends on whether the actual draft required is less than or equal to the maximum draft allowed by the friction conditions.

Step 2: Key Formula or Approach:
The actual draft, d, is the difference between the initial thickness (h_i) and the final thickness (h_f).

$$d = h_i - h_f$$

The maximum possible draft, $d_{\max}$, is determined by the coefficient of friction (μ) and the roll radius (R).

$$d_{\max} = \mu^2 R$$

The process is feasible if $d \leq d_{\max}$.

Step 3: Detailed Explanation:
Given data:

- Initial thickness, $h_i = 30$ mm
- Final thickness, $h_f = 27$ mm
- Roll diameter $= 500$ mm, so Roll radius, $R = 250$ mm
- Coefficient of friction, $\mu = 0.12$

First, calculate the actual draft for the operation:

$$d = 30 - 27 = 3 \text{ mm}$$

Next, calculate the maximum possible draft:

$$d_{\max} = (0.12)^2 \times 250$$

$$d_{\max} = 0.0144 \times 250 = 3.6 \text{ mm}$$

Now, check for feasibility by comparing the actual draft to the maximum draft:

$$d \leq d_{\max} \implies 3 \text{ mm} \leq 3.6 \text{ mm}$$

The condition is satisfied, so the process is **feasible**.
The question asks for the feasibility and the **maximum draft**. The maximum draft we calculated is 3.6 mm.

Step 4: Final Answer:
The process is feasible, and the maximum draft is 3.6 mm.

> Quick Tip
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> For rolling problems, the condition $d \leq \mu^2 R$ is the key to determining feasibility. Always distinguish between the actual draft of the operation and the maximum possible draft allowed by friction.

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

(A) arc welding
(B) laser welding
(C) gas welding
(D) friction welding

Correct Answer: (B) laser welding

Solution:

Step 1: Understanding the Question:
The question asks to identify the most suitable welding process for creating tailor-welded blanks (TWBs), which are common in the automotive industry and often involve joining sheets of different thicknesses or materials.

Step 2: Detailed Explanation:
Tailor-welded blanks are made by welding flat sheets of metal together before they are stamped into their final shape (e.g., a car door panel). The welding process for this application must have specific characteristics:

- **Low Heat Input and Narrow Heat-Affected Zone (HAZ):** To minimize distortion and maintain the mechanical properties of the parent metals.
- **High Welding Speed:** For mass production efficiency.
- **High-Quality Weld:** The weld seam must be strong and ductile enough to withstand the subsequent stamping/forming process.

Let's analyze the options based on these requirements:

- **Arc welding (e.g., MIG, TIG):** These processes have a relatively high heat input and create a wider HAZ, which can lead to distortion and reduce the formability of the blank.
- **Laser welding (specifically Laser Beam Welding - LBW):** This process uses a highly concentrated energy source. It is characterized by very high welding speeds, extremely low

heat input, a very narrow weld bead, and a minimal HAZ. These properties make it the ideal and most commonly used process for fabricating TWBs, as it produces a high-quality weld with minimal distortion that performs well during forming.

- **Gas welding (e.g., Oxy-acetylene):** This process has very low energy density and extremely high heat input, leading to massive distortion and a wide HAZ. It is completely unsuitable for this application.
- **Friction welding:** This is a solid-state welding process that produces high-quality welds. However, it is typically used to join components with circular cross-sections (like rods and pipes) and is not suitable for welding large, flat sheets together.

Step 3: Final Answer:
Laser welding is the preferred method for fabricating tailor-welded blanks due to its high speed, low heat input, and the high quality of the resulting weld.

> Quick Tip
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> When you see "tailor-welded blanks" or "automotive sheet metal joining," immediately think of high-energy density processes like Laser Beam Welding for its precision, speed, and low distortion.

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

(A) $(AB)^T = B^T A^T$
(B) $AB = BA$
(C) $A^T = A^{-1}$
(D) $A = A^{-1}$

Correct Answer: (A) $(AB)^T = B^T A^T$

Solution:

Step 1: Understanding the Question:
The question provides that A and B are real symmetric matrices and asks to identify the correct statement among the given options. A matrix M is symmetric if $M^T = M$.

Step 2: Detailed Explanation:
Let's analyze each option:

- **(A)** $(AB)^T = B^T A^T$**:** This is the general "reversal rule" for the transpose of a product of matrices. This property is true for **any** two matrices A and B for which the product AB is defined. It does not depend on whether the matrices are symmetric or not. Since it is a universally true mathematical identity, it is correct in this specific case as well.

- **(B)** $AB = BA$**:** This states that the matrices commute. The product of two symmetric matrices is symmetric if and only if they commute. However, symmetric matrices do not commute in general. For example, let $A = \begin{pmatrix} 1 & 2 \\ 2 & 1 \end{pmatrix}$ and $B = \begin{pmatrix} 3 & 4 \\ 4 & 5 \end{pmatrix}$. Both are symmetric. $AB = \begin{pmatrix} 11 & 14 \\ 10 & 13 \end{pmatrix}$ and $BA = \begin{pmatrix} 11 & 10 \\ 14 & 13 \end{pmatrix}$. Clearly, $AB \neq BA$. So, this option is incorrect.
- **(C)** $A^T = A^{-1}$**:** This is the definition of an orthogonal matrix. A symmetric matrix is not necessarily orthogonal. For example, the matrix $A = \begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$ is symmetric, but $A^{-1} = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix}$, which is not equal to $A^T = A$. So, this is incorrect.
- **(D)** $A = A^{-1}$**:** This is the definition of an involutory matrix, where $A^2 = I$. A symmetric matrix is not necessarily involutory. Using the same example $A = \begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$, we have $A \neq A^{-1}$. So, this is incorrect.

Step 3: Final Answer:
The only statement that is always true is the general property of matrix transposition, $(AB)^T = B^T A^T$. The other statements are conditions that apply only to specific subsets of symmetric matrices.

Quick Tip

Remember the fundamental properties of matrix operations. The reversal rule for transpose, $(AB)^T = B^T A^T$, and for inverse, $(AB)^{-1} = B^{-1}A^{-1}$, are always true for any conforming matrices.
