Detailed Analysis of GATE 2015 Paper

GATE ME Solved 2015 Paper (Set 1) Detailed Analysis

Subject	Topic	1 Mark Questions	2 Marks Questions	Total Questions	Total Marks
General Ability	Numerical Ability	1	4	5	9
	Verbal Ability	4	1	5	6
Total Marks					**15**
Engineering Maths	Linear Algebra	1	1	2	3
	Probability and Distribution	1	0	1	1
	Numerical Method	1	1	2	3
	Calculus	2	1	3	4
	Laplace Transform	0	1	1	2
Total Marks					**13**
Engineering Mechanics	Statics	2	0	2	2
	Dynamics	0	1	1	2
Total Marks					**4**
Strength of Materials	Shear Force & Bending Moment	0	1	1	2
	Mohr's Circle	1	0	1	1
	Area Moment of Inertia	0	1	1	2
Total Marks					**5**
Theory of Machines	Mechanism	1	2	3	5
	Gear Trains	1	0	1	1
	Vibration	1	1	2	3
	Flywheel	0	1	1	2
Total Marks					**11**
Machine Design	Design for Dynamic Loading	1	0	1	1
	Design of Joints	0	1	1	2
	Design of Bearings	0	1	1	2
Total Marks					**5**
Fluid Mechanics	Fluid Dynamic	1	0	1	1
	Flow Through Pipes	1	0	1	1
	Fluid Kinematics	0	1	1	2
	Hydraulic Machine	0	1	1	2
Total Marks					**6**
Heat Transfer	Conduction	0	1	1	2
	Convection	1	0	1	1
	Radiation	0	1	1	2
	Heat Exchanger	1	0	1	1
Total Marks					**6**
Thermodynamics	Basic Thermodynamics	0	2	2	4
	Power Engineering	1	0	1	1
	Thermodynamic Cycle and Property Relations	1	0	1	1
	Refrigeration	0	2	2	4

	Properties of Gases and Pure Substances	1	1	2	3
Total Marks					**13**
Manufacturing Process Engineering	Engineering Materials	1	0	1	1
	Casting	1	2	3	5
	Forming Process	0	1	1	2
	Joining Process	1	0	1	1
	Machining and Machine Operation	1	2	3	5
	Computer Integrated Manufacturing	1	1	2	3
Total Marks					**17**
Industrial Engineering	Operational Research	0	1	1	2
	Inventory Control	0	1	1	2
	Production Planning & Control	1	0	1	1
Total Marks					**5**

GATE ME Solved 2015 Paper (Set 2) Detailed Analysis

Subject	Topic	1 Mark Questions	2 Marks Questions	Total Questions	Total Marks
General Ability	Numerical Ability	1	4	5	9
	Verbal Ability	4	1	5	6
Total Marks					**15**
Engineering Maths	Linear Algebra	1	0	1	1
	Probability and Distribution	1	1	2	3
	Numerical Method	1	1	2	3
	Calculus	1	0	1	1
	Differential Equation	0	1	1	2
	Complex Variable	1	0	1	1
Total Marks					**11**
Engineering Mechanics	Statics	1	1	2	3
	Dynamics	2	2	4	6
Total Marks					**9**
Strength of Materials	Simple Stress & Strain	1	0	1	1
	Deflection of Beams	0	1	1	2
	Torsion	1	0	1	1
	Column	1	0	1	1
Total Marks					**5**
Theory of Machines	Mechanism	1	0	1	1
	Gear Trains	0	1	1	2
	Vibration	0	3	3	6
Total Marks					**9**
Machine Design	Design for Static Loading	0	1	1	2
	Design for Dynamic Loading	1	0	1	1
	Design of Joints	0	1	1	2
Total Marks					**5**
Fluid Mechanics	Fluid Dynamic	0	1	1	2

	Flow Through Pipes	1	1	2	3
	Boundary Layer	1	1	1	1
	Fluid Kinematics	0	2	2	4
Total Marks					**10**
Heat Transfer	Conduction	0	1	1	2
	Convection	1	1	2	3
Total Marks					**5**
Thermodynamics	Basic Thermodynamics	2	2	4	6
	Power Engineering	0	1	1	2
	Thermodynamic Cycle and Property Relations	1	0	1	1
	Psychrometrics	1	0	1	1
Total Marks					**10**
Manufacturing Process Engineering	Joining Process	1	1	2	3
	Machining and Machine Operation	1	1	2	3
	Metrology and Inspection	1	2	3	5
	Computer Integrated Manufacturing	1	1	2	3
	Metal Cutting	1	1	2	3
Total Marks					**17**
Industrial Engineering	Forecast	0	1	1	2
	PERT & CPM	0	1	1	2
Total Marks					**4**

GATE ME Solved 2015 Paper (Set 3) Detailed Analysis

Subject	Topic	1 Mark Questions	2 Marks Questions	Total Questions	Total Marks
General Ability	Numerical Ability	1	4	5	9
	Verbal Ability	4	1	5	6
Total Marks					**15**
Engineering Maths	Linear Algebra	1	0	1	1
	Probability and Distribution	1	1	2	3
	Numerical Method	0	1	1	2
	Calculus	1	0	1	1
	Differential Equation	0	1	1	2
	Vector Calculus	1	1	2	3
	Laplace Transform	1	0	1	1
Total Marks					**13**
Engineering Mechanics	Statics	0	1	1	2
	Dynamics	1	1	2	3
Total Marks					**5**
Strength of Materials	Simple Stress & Strain	1	1	2	3
	Shear Force & Bending Moment	0	1	1	2
	Slope & Deflection of Beams	0	1	1	2
	Torsion	0	2	2	4
	Mohr's Circle	1	1	2	3
Total Marks					**14**

Theory of Machines	Mechanism	0	1	1	2
	Gear Trains	1	0	1	1
	Vibration	1	1	2	3
Total Marks					**6**
Machine design	Theories of Failure	1	0	1	1
Total Marks					**1**
Fluid Mechanics	Fluid Dynamic	1	0	1	1
	Flow Through Pipes	0	2	2	4
	Fluid Kinematics	1	0	1	1
Total Marks					**6**
Heat Transfer	Conduction	1	1	2	3
	Convection	1	0	1	1
	Radiation	0	1	1	2
	Heat Exchanger	0	1	1	2
Total Marks					**8**
Thermodynamics	Basic Thermodynamics	1	2	3	5
	Power Engineering	1	1	2	3
	Thermodynamic Cycle and Property Relations	0	1	1	2
	Refrigeration	1	0	1	1
	IC Engine	1	0	1	1
Total Marks					**12**
Manufacturing Process Engineering	Engg Materials	1	0	1	1
	Casting	0	1	1	2
	Forming Process	0	1	1	2
	Joining Process	0	1	1	2
	Metrology and Inspection	1	0	1	1
	Computer Integrated Manufacturing	1	0	1	1
	Advance Machining	1	1	2	3
	Metal Cutting	0	1	1	2
Total Marks					**14**
Industrial Engineering	Operational Research	1	1	2	3
	Inventory Control	1	1	2	3
Total Marks					**6**

GATE 2015 Solved Paper
ME: Mechanical Engineering
Set – I

Number of Questions: 65 **Total Marks:100.0**

Wrong answer for MCQ will result in negative marks, (−1/3) for 1 Mark Questions and (−2/3) for 2 Marks Questions.

General Aptitude

Number of Questions: 10 **Section Marks: 15.0**

Q.1 to Q.5 carry 1 mark each and Q.6 to Q.10 carry 2 marks each.

Question Number: 1 **Question Type: MCQ**

Select the appropriate option in place of underlined part of the sentence.

Increased productivity necessary reflects greater efforts made by the employees.

(A) Increase in productivity necessary
(B) Increase in productivity is necessary
(C) Increase in productivity necessarily
(D) No improvement required

Solution: The given sentence is incorrect. The use of 'necessary' is incorrect. 'Necessary' here is an adjective and it is incorrect. The sentence requires the use of an adverb which would define 'reflects' that is a verb. 'Increase in' is a better usage than 'increased' as the latter would mean that 'productivity' increased by itself, which is illogical.
Hence, the correct option is (C).

Question Number: 2 **Question Type: MCQ**

Given below are two statements followed by two conclusions. Assuming these statements to be true, decide which one logically follows.

Statements:

(I) No manager is leader.

(II) All leaders are executives.

Conclusions:

(I) No manager is an executive

(II) No executive is a manager

(A) Only conclusion I follows
(B) Only conclusion II follows
(C) Neither conclusions I nor II follows
(D) Both conclusions I and II follows

Solution: No manager is a leader

This is a universal negative statement where manager and leader both are distributed.

All leaders are executives is a universal affirmative statement.

Where subject is distributed and predicate is not.

So the conclusion has to be of the form of universal negative or particular negative.

No manager is an executive, also

No executive is a manager

In either of the statements, both manager and executive are distributed.

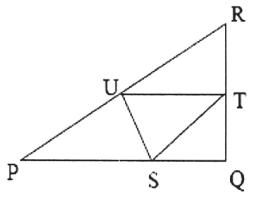
So it satisfies all the rules. But it does not satisfy the rule,

"If a term distributed in the conclusion should be distributed in the premises also. But executives is not distributed in the premise".

Both conclusions do not follow.
Hence, the correct option is (C).

Question Number: 3 **Question Type: NAT**

In the given figure, angle Q is a right angle, PS:QS = 3:1, RT:QT = 5:2 and PU:UR = 1:1. If the area of triangle QTS is 20 cm^2, then the area of triangle PQR in cm^2 is _____.



Solution:

$$\text{Area of triangle } PQR = \frac{1}{2}(QR)(PQ)$$

$$= \frac{1}{2}(QT + TR)(PS + SQ)$$

$$= \frac{1}{2}\left(QT + \frac{5}{2}QT\right)(3SQ + SQ)$$

$$= 14 \text{ (Area of triangle } QTS)$$

$$= 14\,(20) = 280$$

Hence, the correct answer is 280.

Question Number: 4 **Question Type: MCQ**

Right triangle PQR is to be constructed in the xy plane so that the right angle is at P and line PR is parallel to the x-axis. The x and y coordinates of P, Q and R are to be integers that satisfy the inequalities: $-4 \leq x \leq 5$ and $6 \leq y \leq 16$. How many different triangles could be constructed with these properties?

(A) 110 (B) 1,100
(C) 9,900 (D) 10,000

Solution: PR is parallel to the x-axis.

$\therefore$ The y-coordinates of P and R are the same.

The triangle PQR is right angled at P.

$\therefore$ The x-coordinates of P and Q are the same.

The x and y coordinates of P, Q, and R are to be integers satisfying the inequalities $-4 \leq x \leq 5$ and $6 \leq y \leq 16$.

The x and y coordinates of P have 10 and 11 possible values, respectively

$\therefore$ The coordinates of P have (10) (11) possible values, i.e., 110 possible values.

For each possible location of P, R has 9 possible locations ($\because$ R must have the same y coordinate as P, and it must have some x coordinate other than that of P).

Similarly, for each possible location of P, Q has 10 possible locations.

$\therefore$ Number of different triangles which could be constructed $= (90)\ (110) = 9900$.
Hence, the correct option is (C).

Question Number: 5 **Question Type: MCQ**

A coin is tossed thrice. Let X be the event that head occurs in each of the first two tosses. Let Y be the event that a tail occurs on the third toss. Let Z be the event that two tails occur in three tosses. Based on the above information, which one of the following statements is TRUE?

(A) X and Y are not independent
(B) Y and Z are dependent
(C) Y and Z are independent
(D) X and Z are independent

Solution: X is the event of getting HH. $P(X) = \frac{2}{8}$

Y is the event of getting H $P(Y) = \frac{4}{8}$

Z is the event of getting TTH or THT or HTT

$\therefore$ $P(Z) = \frac{3}{8}$

Two events A and B are said to be independent if $P(A \cap B)$ equals $P(A)$ multiplied by $P(B)$. Otherwise, those events are said to be dependent.

$P(Y \cap Z) = P$

(Tails occurring in the third toss and in one other toss) $= P$

(THT or HTT) $= \frac{2}{8}$

$$P(Z) \times P(Y) = \frac{3}{8} \times \frac{1}{2} = \frac{3}{16}$$

$\therefore$ As $P(Z \cap Y) \neq P(Z) \times P(Y)$, Y and Z are dependent.

Hence, the correct option is (B).

Question Number: 6 **Question Type: MCQ**

Choose the appropriate word/phrase, out of the four options given below, to complete the following sentence:
Apparent lifelessness _____ dormant life

(A) harbours (B) leads to
(C) supports (D) affects

Solution: The correct option is (A).

Question Number: 7 **Question Type: MCQ**

Fill in the blank with the correct idiom/phrase.

That boy from the town was a _____ in the sleepy village

(A) dog out of herd (B) sheep from the heap
(C) fish out of water (D) bird from the flock

Solution: 'Fish out of water' means to be out of place. The other choices are incorrect as they do not exist.
Hence, the correct option is (C).

Question Number: 8 **Question Type: MCQ**

Choose the statement where underlined word is used correctly.

(A) When the teacher eludes to different authors, he is being elusive.
(B) When the thief keeps eluding the police, he is being elusive.
(C) Matters that are difficult to understand, identify or remember are allusive.
(D) Mirages can be allusive, but a better way to express them is illusory.

Solution: 'Elusive' means hard to find or capture. 'Allusive' means a statement that refers to something without actually mentioning it. Only choice (B) uses the word correctly.
Hence, the correct option is (B).

Question Number: 9 **Question Type: MCQ**

Tanya is older than Eric.

Cliff is older than Tanya.

Eric is older than Cliff.

If the first two statements are true, then the third statement is:

(A) True (B) False
(C) Uncertain (D) Data insufficient

Solution: Tanya is older than Eric can be represented as $T > E$

Clift is older than Tanya can be represented as $C > T$

Combining both of them, we get $C > T > E$

This implies that Clift is older than Eric, meaning that Eric is older than Clift is False.

Hence, the correct option is (B).

Question Number: 10 **Question Type: MCQ**

Five teams have to compete in a league, with every team playing every other team exactly once, before going to the next round. How many matches will have to be held to complete the league round of matches?

(A) 20 (B) 10
(C) 8 (D) 5

Solution: Every team plays every other team exactly once.

$\therefore$ Each pair of teams plays a match and they are $\frac{5\times4}{2}$, i.e., 10 pairs.

A total of 10 matches will have to be held to complete the league round of matches.

Hence, the correct option is (B).

Mechanical Engineering

Number of Questions: 55 **Section marks: 85.0**

Q.11 to Q.35 carry 1 mark each and Q.36 to Q.65 carry 2 marks each.

Question Number: 11 **Question Type: MCQ**

An air-standard diesel cycle consists of the following processes.

1 – 2: Air is compressed isentropically.

2 – 3: Heat is added at constant pressure.

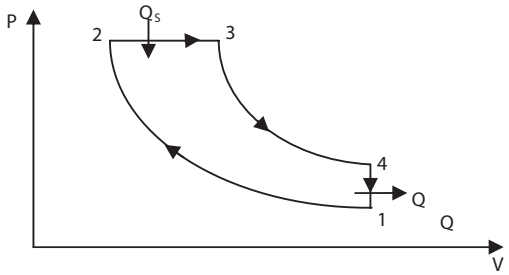
3 – 4: Air expands isentropically to the original volume.

4 – 1: Heat is rejected at constant volume

If γ and T denote the specific heat ratio and temperature, respectively, the efficiency of the cycle is

(A) $1-\frac{T_4\ T_1}{T_3\ T_2}$ (B) $1-\frac{T_4-T_1}{\gamma(T_3-T_2)}$

(C) $1-\frac{\gamma(T_4-T_1)}{T_3-T_2}$ (D) $1-\frac{T_4-T_1}{(\gamma-1)(T_3-T_2)}$



Solution: $\eta=\frac{Q_S-Q_R}{Q_S}$

$$\Rightarrow\eta=\frac{(h_3-h_2)-(h_4-h_1)}{(h_3-h_2)}$$

$$\Rightarrow\eta=\frac{mC_P(T_3-T_2)-mC_V(T_4-T_1)}{mC_P(T_3-T_2)}$$

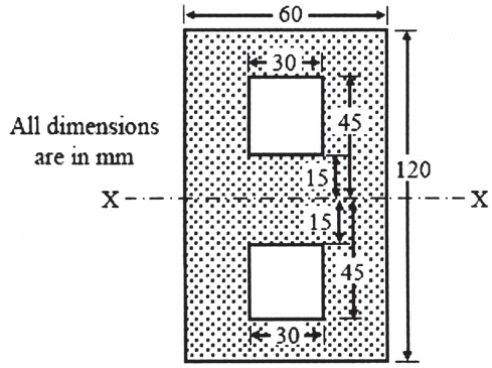
$$\Rightarrow\eta=1-\frac{mC_V(T_4-T_1)}{mC_P(T_3-T_2)}$$

$$\Rightarrow\eta=1-\frac{(T_4-T_1)}{\gamma(T_3-T_2)}$$

Hence, the correct option is (B).

Question Number: 12 **Question Type: MCQ**

The value of moment of inertia of the section shown in the figure about the axis-XX is



(A) 8.5050×10^6 mm^4 (B) 6.8850×10^6 mm^4
(C) 7.7625×10^6 mm^4 (D) 8.5725×10^6 mm^4

Solution: Moment of inertia of the section about XX axis,

$$I_{XX}=[I_1-(I_2+I_3)]_{XX}$$

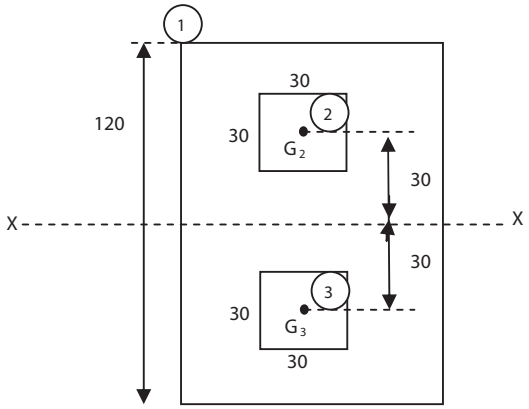
Due to symmetry, $I_2=I_3=I_G+Ah^2$

where I_G = Moment of inertia about center of gravity

A = Area of cross-section.

h = Distance between center of gravity and XX axis.

Now, $$(I)_{XX}=\frac{bd^3}{12}=\frac{60\times120^3}{12}$$



$$(I_2)_{XX} = \frac{bd^3}{12} + Ah^2 = \left(\frac{30\times30^3}{12}\right) + [30 \times 30 \times 30^2]$$

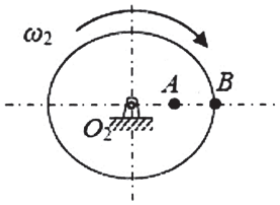
$$(I_2)_{XX} = \left[\frac{60\times120^3}{12}\right] - \left[2\times\left\{\frac{30^4}{12} + 30^4\right\}\right]$$

$$I_{XX} = 6.8850 \times 10^6 \text{ mm}^4$$

Hence, the correct option is (B).

Question Number: 13 **Question Type: NAT**

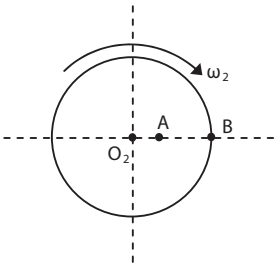
Figure shows a wheel rotating about O_2. Two points A and B located along the radius of wheel have speeds of 80 m/s and 140 m/s, respectively. The distance between the points A and B is 300 mm. The diameter of the wheel (in mm) is _____.



Solution: Let $O_2 B = r_B$ and $O_2 A = r_A$

Now $V_A = \omega_2 r_A$

$$\Rightarrow \quad \omega_2 = \frac{V_A}{r_A} \text{ and } V_B = \omega_2 r_B$$



$$\Rightarrow \quad \omega_2 = \frac{V_B}{r_B}$$

$$\therefore \frac{V_A}{r_A} = \frac{V_B}{r_B} \Rightarrow \frac{80}{r_A} = \frac{140}{r_B}$$

$$\Rightarrow \quad 80\, r_B - 140\, r_A = 0 \rightarrow (1)$$

$$r_B - r_A = 300 \text{ mm} \rightarrow (2) \qquad \text{[given]}$$

From Eqs. (1) and (2), we get $r_B = 700$ mm

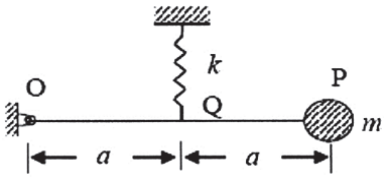
$\Rightarrow$ Diameter of the wheel, $D = 2r_B = 2 \times 700$

$$\therefore \quad D = 1400 \text{ mm}$$

Hence, the correct answer is 1390 to 1410.

Question Number: 14 **Question Type: MCQ**

Figure shows a single degree of freedom system. The system consists of a massless rigid bar OP hinged at O and mass m at end P. The natural frequency of vibration of the system is _____.

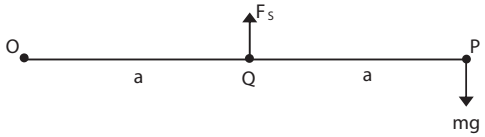


(A) $f_n = \frac{1}{2\pi}\sqrt{\frac{k}{4m}}$ (B) $f_n = \frac{1}{2\pi}\sqrt{\frac{k}{2m}}$

(C) $f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (D) $f_n = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}$

Solution:

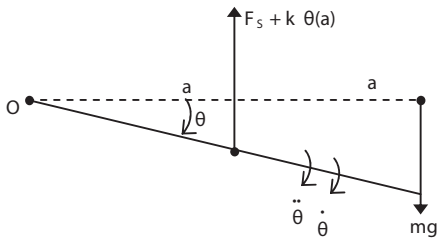
Static free-body diagram



$$\Sigma M_o = 0 \Rightarrow -mg(2a) + F_s(a) = 0 \qquad (1)$$

Dynamic free-body diagram

$$\Sigma M_o = I_o\left(-\ddot{\theta}\right)$$



$$\Rightarrow \quad -mg(2a) + [F_S + k\,\theta(a)]a = I_o\left(-\ddot{\theta}\right) \Rightarrow mg(2a) + F_S(a) + k\,\theta(a^2) = I_o\left(-\ddot{\theta}\right)$$

$$\Rightarrow \quad 0 + I_o\left(\ddot{\theta}\right) + k\,\theta(a^2) = 0 \qquad \text{[From Eq. (1)]}$$

$$\Rightarrow \quad m(2a)^2\,\ddot{\theta} + k(a^2)\,\theta = 0$$

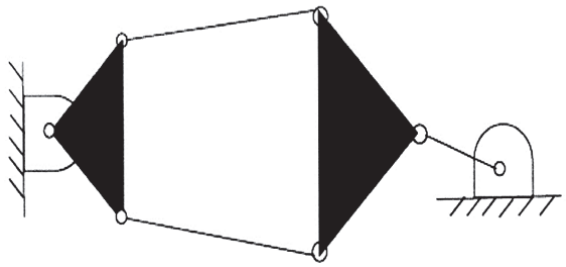
$$\Rightarrow \quad \ddot{\theta} + \left(\frac{ka^2}{4ma^2}\right)\theta = 0$$

$$\therefore \quad \omega_n = \sqrt{\frac{k}{4m}} \text{ or } f_n = \frac{1}{2\pi}\sqrt{\frac{k}{4m}}$$

Hence, the correct option is (A).

Question Number: 15 **Question Type: MCQ**

The number of degrees of freedom of the linkage shown in the figure is



(A) −3 (B) 0
(C) 1 (D) 2

Solution: No. of links = 6 (n)
No. of binary joints = 7 (P)
Degrees of freedom = $3(n-1) - 2P$
$= 3 \times 5 - 2 \times 7 = 1$

Hence, the correct option is (C).

Question Number: 16 **Question Type: NAT**

For ball bearings, the fatigue life L measured in the number of revolutions and the radial load F are related by $FL^{1/3} = K$, where K is a constant. It withstands a radial load of 2 kN for a life of 540 million revolutions. The load (in kN) for a life of one million revolutions is _____.

Solution:

$$FL^{1/3} = K$$

$$F_1 = 2 \text{ kN}, L_1 = 540 \text{ Mrev}$$

$$L_2 = 1 \text{ Mrev} \Rightarrow (2 \times 10^3)\cdot(540 \times 10^6)^{1/3} = K$$

$$\Rightarrow \quad K = 1628650.57$$

$$\therefore \quad F_2 \cdot L_2^{1/3} = K$$

$$\therefore \quad F_2 = K \cdot L_2^{-1/3}$$

$$F_2 = 16.286 \text{ kN}$$

Hence, the correct answer is 15 to 17.

Question Number: 17 **Question Type: NAT**

In a rolling operation using rolls of diameter 500 mm, if a 25 mm thick plate cannot be reduced to less than 20 mm in one pass, the coefficient of friction between the roll and the plate is _____.

Solution: Change in thickness ($\triangle h$) = 25 – 20 = 5 mm

Roll diameter = 500 mm $\Rightarrow R$ = 250 mm

$$\therefore \quad \triangle h = \mu^2 R$$

$$\therefore \quad 5 = \mu^2\,250 \Rightarrow \mu = \sqrt{\frac{1}{50}} = 0.141$$

Hence, the correct answer is 0.10 to 0.15.

Question Number: 18 **Question Type: NAT**

Ratio of solidification time of a cylindrical casting (height = radius) to that of a cubic casting of side two times the height of cylindrical casting is _____.

Solution: Solidification time $\propto \left(\frac{V}{SA}\right)^2$

T_{Cy} = solidification time of cylinder casting

$$= \left(\frac{\pi r^2 h}{2\pi r^2 + 2\pi rh}\right)^2$$

$$r = h$$

$$\therefore \quad T_{Cy} = \left(\frac{\pi r^3}{4\pi r^2}\right)^2 = \left(\frac{r}{4}\right)^2 = \frac{h^2}{16}$$

T_{Cu} = solidification time of cubic casting

$$= \left(\frac{a^3}{6a^2}\right)^2 = \left(\frac{a}{6}\right)^2 = \left(\frac{a}{6}\right)^2 = \frac{a^2}{36}$$

$$a = 2h$$

$$\therefore \quad T_{Cu} = \frac{h^2}{9}$$

$$\therefore \quad T_{Cy}:T_{Cu} = 9:16 = 0.5625$$

Hence, the correct answer is 0.5 to 0.6.

Question Number: 19 **Question Type: NAT**

The annual requirement of rivets at a ship manufacturing company is 2000 kg. The rivets are supplied in units of 1 kg costing ₹25 each. If it costs ₹100 to place an order and the annual cost of carrying one unit is 9% of its purchase cost, the cycle length of the order (in days) will be _____.

Solution: Annual requirement D = 2000 kg

$$\text{Unit cost} = ₹25/\text{kg}$$

$$\text{Carrying cost} = C_C = 9\% \text{ of unit cost}$$

$$= \frac{9}{100} \times 25 = ₹2.25/\text{unit/year}$$

$$\text{Ordering cost} = C_o = ₹100/\text{order}$$

$$q = \text{optimum order quantity}$$

$$= \sqrt{\frac{2DC_o}{C_C}} = \sqrt{\frac{2\times2000\times100}{2.25}}$$

$$= 421.64 \text{ kg}$$

$$\therefore \text{No. of orders} = \frac{D}{q} = \frac{2000}{421.64} = 4.743$$

$$\text{Cycle length} = \frac{365}{4.743} = 76.948 \Rightarrow 77 \text{ days}$$

Hence, the correct answer is 76 to 78.

Question Number: 20 **Question Type: MCQ**

Orthogonal turning of a mild steel tube with a tool of rake angle 10° is carried out at a feed of 0.1 mm/rev. If the thickness of the chip produced is 0.28 mm, the values of shear angle and shear strain will be respectively

(A) 28° 20′ and 2.19 (B) 22°20′ and 3.53
(C) 24°30′ and 4.19 (D) 37°20′ and 5.19

Solution:

Rake angle, $\alpha = 10°$, feed = 0.14 mm/rev

Chip thickness, $t_c = 0.28$ mm

The initial thickness of the chip in turning is given by the feed, i.e., $t = 0.14$ mm

$$\therefore \quad r = \frac{t}{t_C} = \frac{0.14}{0.28} = 0.5$$

$$r = \frac{\sin\varphi}{\cos(\varphi-\alpha)} = 0.5$$

$$\Rightarrow \frac{\cos\varphi\cos\alpha + \sin\varphi\sin\alpha}{\sin\varphi} = 2$$

$$\therefore \quad \cot\varphi \ \cos\alpha + \sin\alpha = 2$$

$$\therefore \quad \varphi = 28.33°$$

$$\text{Shear strain} = \delta = \cot\varphi + \tan(\varphi - \alpha)$$

$$= \cot(28.33) + \tan(28.33 - 10) = 2.186$$

Hence, the correct option is (A).

Question Number: 21 **Question Type: MCQ**

In a CNC milling operation, the tool has to machine the circular arc from point (20, 20) to (10, 10) at a sequence number 5 of the CNC part program. If the center of the arc is at (20, 10) and the machine has incremental mode of defining position coordinates, the correct tool path command is

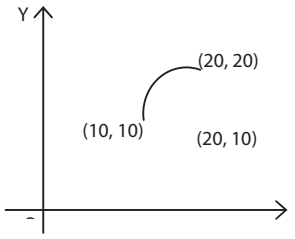
(A) *N*05 *G*90 *G*01 *X*-10 *Y*-10 *R*10
(B) *N*05 *G*91 *G*03 *X*-10 *Y*-10 *R*10
(C) *N*05 *G*90 *G*03 *X*20 *Y*20 *R*10
(D) *N*05 *G*91 *G*02 *X*20 *Y*20 *R*10

Solution: From the given points, (20, 20) to (10, 10) with center at (20, 10), the radius of the circular arc is 10. The tool starts at (20, 20) and traverse counter clockwise with a radius 10 and center at (20, 10) upto the point (10, 10).

The sequence number is 5 ⇒ *N*05

Incremental input ⇒ *G*91

Counter clockwise circular interpolation ⇒ *G*03



The tool being at point (20, 20) takes it as origin. The end point (10, 10) is given by *X*-10, *Y*-10.

∴ The command is

*N*05 *G*91 *G*03 *X*-10 *Y*-10 *R*10

Hence, the correct option is (B).

Question Number: 22 **Question Type: NAT**

A Prandtl tube (Pitot-static tube with $C = 1$) is used to measure the velocity of water. The differential manometer reading is 10 mm of liquid column with a relative density of 10. Assuming $g = 9.8$ m/s², the velocity of water (in m/s) is _____.

Solution:

$$\text{Velocity of water} = C\sqrt{2gh} = \sqrt{2gh} \quad [\because C = 1]$$

$$h = x\left[\frac{S_g}{S_w} - 1\right] = 10\left[\frac{10}{1} - 1\right] = 90 \text{ mm or } h = 0.09 \text{ m}$$

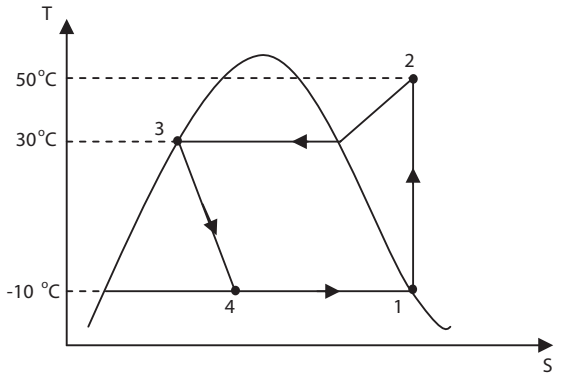
$$\text{Velocity of water} = \sqrt{2\times9.81\times0.09} = 1.3288 \text{ m/s}$$

Hence, the correct answer is 1.30 to 1.34.

Question Number: 23 **Question Type: NAT**

Refrigerant vapor enters into the compressor of a standard vapor compression cycle at –10°C ($h = 402$ kJ/kg) and leaves the compressor at 50°C ($h = 432$ kJ/kg). It leaves the condenser at 30°C ($h = 237$ kJ/kg). The COP of the cycle is _____.

Solution:



Given:

$$h_1 = 402 \text{ kJ/kg}, h_2 = 432 \text{ kJ/kg},$$
$$h_3 = h_4 = 237 \text{ kJ/kg}$$
$$COP = \frac{R.E}{W} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{402 - 237}{432 - 402}$$

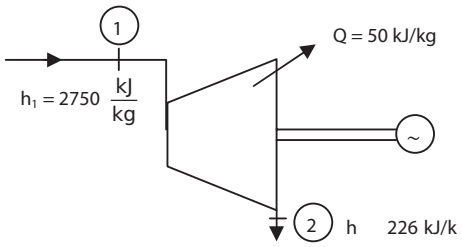
$\therefore \quad COP = 5.5$

Hence, the correct answer is 5.5.

Question Number: 24 **Question Type: NAT**

Steam enters a turbine at 30 bar, 300°C (u = 2750 kJ/kg, h = 2993 kJ/kg) and exits the turbine as saturated liquid at 15 kPa (u = 225 kJ/kg, h = 226 kJ/kg). Heat loss to the surrounding is 50 kJ/kg of steam flowing through the turbine. Neglecting changes in kinetic energy and potential energy, the work output of the turbine (in kJ/kg of steam) is _____.

Solution:



Neglecting △K.E and △P.E, SFEE is

$$h_1 + Q = h_2 + W \Rightarrow W = (h_1 - h_2) + Q$$

$\therefore \quad W = (2750 - 226) - 50 = 2717 \text{ kJ/kg}$

Hence, the correct answer is 2717.

Question Number: 25 **Question Type: NAT**

Air in a room is at 35°C and 60% relative humidity (RH). The pressure in the room is 0.1 MPa. The saturation pressure of water at 35°C is 5.63 kPa. The humidity ratio of the air (in gram/kg of dry air) is _____.

Solution: $\text{RH} = 0.6 = \frac{P_V}{P_S} \Rightarrow P_V = 0.6 \times 5.63$

$\Rightarrow \quad P_V = 3.378 \text{ kPa}$

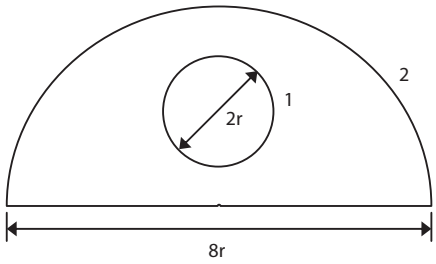
Humidity ratio, $\omega = 0.622 \frac{P_V}{P\ P_V} = 0.622 \times \frac{3.378}{100 - 3.378}$

$\therefore \omega = 0.0217457$ kg/kg of dry air

or $\omega = 21.7457$ gram/kg of dry air.

Hence, the correct answer is 21.7 to 21.9.

Question Number: 26 **Question Type: MCQ**

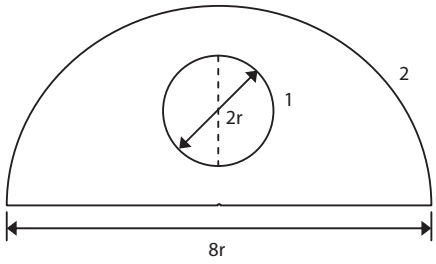


A solid sphere 1 of radius 'r' is placed inside a hollow, closed hemispherical surface 2 of radius '$4r$'. The shape factor F_{2-1} is

(A) 1/12 (B) 1/2

(C) 2 (D) 12

Solution:



$$F_{11} + F_{12} = 1 \Rightarrow F_{12} = 1 \quad [\because F_{11} = 0]$$
$$A_1 F_{12} = A_2 F_{21} \Rightarrow 4\pi\ (r)^2 \times F_{12} = 3\pi\ (4r)^2 \times F_{21}$$

$\therefore \quad F_{21} = \frac{4\pi r^2}{3\pi \times 16 r^2} = \frac{1}{12}$

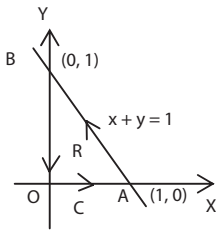
Hence, the correct option is (A).

Question Number: 27 **Question Type: NAT**

The value of $\int_C [(3x - 8y^2)dx + (4y - 6x)dy]$, (where C is the boundary of the region bounded by $x = 0$, $y = 0$ and $x + y = 1$) is _____.

Solution: We have to evaluate

$$\int_C \left[\left(3x - 8y^2\right)dx + \left(4y - 6xy\right)dy\right]$$



Let $\phi(x, y) = 3x - 8y^2$

and $\Psi(x, y) = 4y - 6xy$

$\therefore \quad \dfrac{\partial \varphi}{\partial y} = -16y$ and $\dfrac{\partial \Psi}{\partial x} = -6y$

and in the region R bounded by C (i.e., triangle OAB), x varies from $x = 0$ to $x = 1 - y$ and y varies from $y = 0$ to $y = 1$.

$$\therefore \quad \int_C \left[\left(3x - 8y^2\right)dx + \left(4y - 6xy\right)dy\right] = \int_C \left[\varphi dx + \Psi dy\right]$$

(By Green's theorem)

$$= \iint_R \left(\frac{\partial \Psi}{\partial x} - \frac{\partial \varphi}{\partial y}\right)dxdy$$

$$= \iint_R [-6y - (-16y)]dxdy$$

$$= \int_{y=0}^{1} \int_{x=0}^{1-y} 10y\,dxdy = \int_{y=0}^{1} (10xy)\Big]_{x=0}^{1-y} dy$$

$$= 10 \int_{y=0}^{1} [(1-y)y - 0 \times y]dy$$

$$= 10 \int_{y=0}^{1} \left[y - y^2\right]dy = 10\left(\frac{y^2}{2} - \frac{y^3}{3}\right)\Bigg|_0^1$$

$$= \frac{5}{3} = 1.66.$$

Hence, the correct answer is 1.60 to 1.70.

Question Number: 28 **Question Type: MCQ**

For a given matrix $P = \begin{bmatrix} 4+3i & -i \\ i & 4-3i \end{bmatrix}$, where $i = \sqrt{-1}$, the inverse of matrix P is

(A) $\dfrac{1}{24}\begin{bmatrix} 4-3i & i \\ -i & 4+3i \end{bmatrix}$ (B) $\dfrac{1}{25}\begin{bmatrix} i & 4-3i \\ 4+3i & -i \end{bmatrix}$

(C) $\dfrac{1}{24}\begin{bmatrix} 4+3i & -i \\ i & 4-3i \end{bmatrix}$ (D) $\dfrac{1}{25}\begin{bmatrix} 4+3i & -i \\ i & 4-3i \end{bmatrix}$

Solution:

Given matrix is $P = \begin{bmatrix} 4+3i & -i \\ i & 4-3i \end{bmatrix}$

Determinant of $P = \begin{vmatrix} 4+3i & -i \\ i & 4-3i \end{vmatrix}$

$$= (4 + 3i)(4 - 3i) + i^2 = 24$$

$\therefore$ Inverse of $P = P^{-1} = \dfrac{1}{|P|}$ (adj P)

$$= \frac{1}{24}\begin{bmatrix} 4-3i & i \\ -i & 4+3i \end{bmatrix}.$$

Hence, the correct option is (A).

Question Number: 29 **Question Type: NAT**

Newton-Raphson method is used to find the roots of the equation, $x^3 + 2x^2 + 3x - 1 = 0$. If the initial guess is $x_0 = 1$, then the value of x after the second iteration is _____.

Solution: Let $f(x) = x^3 + 2x^2 + 3x - 1$

$\Rightarrow \quad f^1(x) = 3x^2 + 4x + 3$

Given $x_0 = 1$

$\therefore \quad f(x_0) = f(1) = 5$ and $f^1(x_0) = f^1(1) = 10$

By Newton – Raphson method, we have

$$X_1 = x_0 - \frac{f(x_0)}{f^1(x_0)}$$

$$= 1 - \frac{5}{10}$$

$\therefore \quad x_1 = \dfrac{1}{2}$

$$\therefore f(x_1) = f\left(\frac{1}{2}\right) = \frac{9}{8} \text{ and } f^1(x_1) = f^1\left(\frac{1}{2}\right) = \frac{23}{4}$$

The value of x after the second iteration is

$$x_2 = x_1 - \frac{f(x_1)}{f^1(x_1)}$$

$$= \frac{1}{2} - \frac{\left(\frac{9}{8}\right)}{\left(\frac{23}{4}\right)}$$

$$= \frac{7}{23} = 0.3043.$$

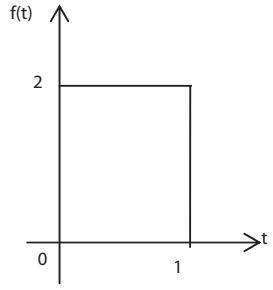
Hence, the correct answer is 0.29 to 0.31

Question Number: 30 **Question Type: MCQ**

Laplace transform of the function $f(t)$ is given by

$$F(s) = L\{f(t)\} = \int_0^\infty f(t)e^{-st}\,dt.$$

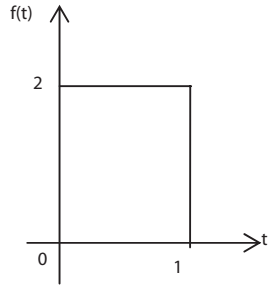
Laplace transform of the function is given by



(A) $\dfrac{1-e^{-2s}}{s}$ (B) $\dfrac{1-e^{-s}}{2s}$

(C) $\dfrac{2-2e^{-s}}{s}$ (D) $\dfrac{1-2e^{-s}}{s}$

Solution:



Given function is

$$f(t) = \begin{cases} 2 : 0 \le t \le 1 \\ 0 : \text{otherwise} \end{cases}$$

The Laplace transform of $f(t)$ is

$$L[f(t)] = \int_0^\infty e^{-st} f(t)dt$$

$$= \int_\partial^1 e^{-st} \times 2dt + \int_1^\infty e^{-st} \times 0dt$$

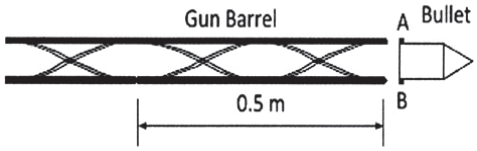
$$= \frac{2e^{-st}}{-s}\Big|_0^1 + 0 = \frac{2}{-s}\left[e^{-s} - 1\right]$$

$$= \frac{2-2e^{-s}}{s}$$

Hence, the correct option is (C).

Question Number: 31 **Question Type: NAT**

A bullet spins as the shot is fired from a gun. For this purpose, two helical slots as shown in the figure are cut in the barrel. Projections A and B on the bullet engage in each of the slots.



Helical slots are such that one turn of helix is completed over a distance of 0.5 m. If velocity of bullet when it exists the barrel is 20 m/s, its spinning speed in rad/s is _____.

Solution: Assume that the loss of energy while traveling in the barrel is nil.

Velocity of the bullet = 20 m/s.

1 turn of helix has a length of 0.5 m, i.e., the bullet turns 1 rotation in a length of 0.5 m.

Time taken to travel 0.5 m $= \dfrac{0.5}{20} = 0.025$ sec.

$\therefore$ The bullet turns 1 rotation in 0.025 sec.

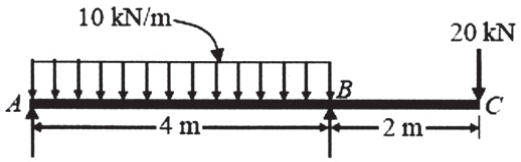
Spinning speed $= \dfrac{1}{0.025} = 40$ rot/sec $= 40 \times 2\ \pi$ rad/sec

$= 251.327$ rad/sec

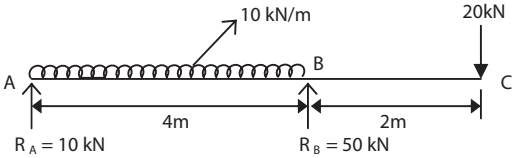
Hence, the correct answer is 251 to 252.

Question Number: 32 **Question Type: NAT**

For the overhanging beam shown in the figure, the magnitude of maximum bending moment (in kN-m) is _____.



Solution:

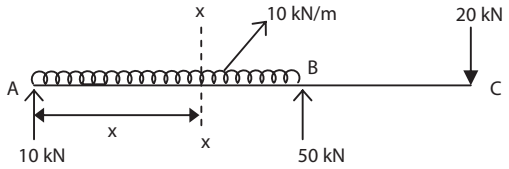


$$R_A + R_B = (10 \times 4) + 20 = 60 \quad (1)$$

$$\Sigma M_C = 0 \Rightarrow R_A \times 6 - 40 \times 4 + R_B + 2 = 0$$

$$\Rightarrow \quad 6R_A + 2R_B = 160 \quad (2)$$

From Eqs. (1) and (2), we get $R_A = 10$ kN and $R_B = 50$ kN



$$M_{X\text{-}X} = 10x - 10 \times \frac{x}{2}$$

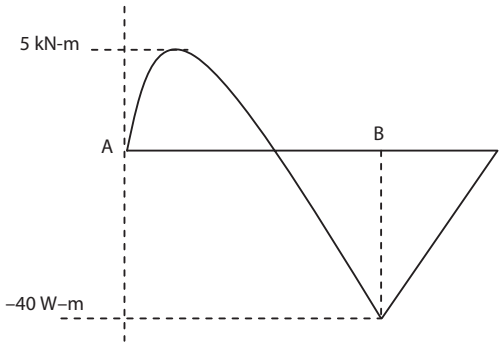
Maximum bending moment in section AB.

$$\frac{dM_{X\text{-}X}}{dx} = 0 \Rightarrow 10 - 10x = 0 \Rightarrow x = 1\,\text{m}$$

$\therefore$ In AB, maximum bending moment

$$(M_{AB})_{max} = 10 \times 1 - 10 \times \frac{1}{2} = 5 \text{ kN-m}$$

At B, $$M_B = 10(4) - \frac{10(4)^2}{2} = -40 \text{ kN-m}$$



Magnitude of maximum bending moment

$= 40$ kN-m.

Hence, the correct answer is 40.

Question Number: 33 **Question Type: NAT**

The torque (in N-m) exerted on the crank shaft of a two stroke engine can be described as $T = 10{,}000 + 1000 \sin 2\theta - 1200 \cos 2\theta$, where θ is the crank angle as measured from inner dead center position. Assuming the resisting torque to be constant, the power (in kW) developed by the engine at 100 rpm is _____.

Solution: $T_{mean} = \frac{1}{\pi}\int_0^{\pi} T d\theta$

$$\Rightarrow T_{mean} = \frac{1}{\pi}\int_0^{\pi} [1000 + 1000\sin 2\theta - 1200\cos 2\theta]\, d\theta$$

$$\Rightarrow T_{mean} = \frac{1}{\pi}\left[10000\theta - \frac{1000}{2}\cos 2\theta - \frac{1200}{2}\sin 2\theta\right]_0^{\pi}$$

$\Rightarrow$ $T_{mean} = 10000$ N-m

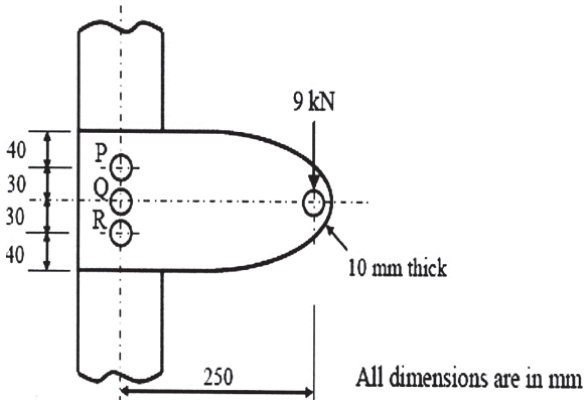
Power developed, $P = T \times \omega = \frac{10000 \times 2\pi \times 100}{60}$

$\therefore$ $P = 104.719$ kW

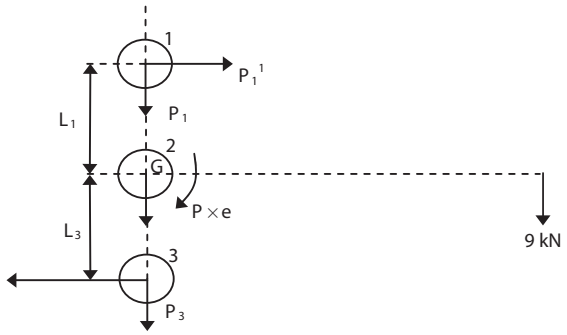
Hence, the correct answer is 104 to 105.

Question Number: 34 **Question Type: NAT**

A cantilever bracket is bolted to a column using three $M12 \times 1.75$ bolts P, Q, and R. The value of maximum shear stress developed in the bolt P (in MPa) is _____.



Solution:



Primary shear force:

$$P_1 = P_3 = P_2 = \frac{9}{3} = 3 \text{ kN}$$

Secondary shear force:

$$P_1^1 = P_3^1 = \frac{Pe(L_1 \text{ or } L_3)}{\left(L_1^2 + L_3^2\right)}$$

$$\Rightarrow P_1^1 + P_3^1 = \frac{9 \times 0.25 \times 0.03}{2 \times 0.03^2} = 37.5\,\text{kN}$$

Resultant force on critical rivet,

$$R = \sqrt{37.5^2 + 3^2} = 37.62\,\text{kN}$$

Maximum shear stress, $T_{max} = \frac{R}{A}$

$$\therefore T_{max} = \frac{37.62\times10^3}{\pi/4\times0.012^2} = 332.632 \text{ MPa}$$

Hence, the correct answer is 332 to 494.

Question Number: 35 **Question Type: MCQ**

A shaft of length 90 mm has a tapered portion of length 55 mm. The diameter of the taper is 80 mm at one end and 65 mm at the other. If the taper is made by tailstock set over method, the taper angle and the set over respectively are

(A) 15° 32' and 12.16 mm
(B) 18° 32' and 15.66 mm
(C) 11° 22' and 10.26 mm
(D) 10° 32' and 14.46 mm

Solution: The angle by which the axis of rotation is shifted is equal to the half angle of taper in tailstock set over method.

$D = 80$ mm, $d = 65$ mm, and taper length $= 55$ mm (l)

$$\tan\alpha = \frac{D-d}{2l} = \frac{80-65}{55} \Rightarrow \alpha = \tan^{-1}\left(\frac{3}{11}\right) = 15.25^\circ$$

The set over is given by $= S = L \times \frac{D-d}{2l}$

$L =$ overall length of shaft $= 90$ mm

$$\therefore \quad S = 90 \times \frac{80-65}{2\times55} = 12.27 \text{ mm}$$

Hence, the correct option is (A).

Question Number: 36 **Question Type: NAT**

The dimensions of a cylindrical side riser (height = diameter) for a 25 cm × 15 cm × 5 cm steel casting are to be determined. For the tabulated shape factor values given below, the diameter of the riser (in cm) is _____.

Shape factor	2	4	6	8	10	12
Riser volume/ Casting volume	1.0	0.70	0.55	0.50	0.40	0.35

Solution: By Naval Research Laboratory method shape factor, $\text{SF} = \frac{\text{length}+\text{width}}{\text{thickness}} = \frac{25+15}{5} = \frac{40}{5} = 8$ for a SF = 8, the volume ratio = 0.5.

$$\therefore \frac{\text{riser volume}}{\text{casting volume}} = 0.5$$

$$\frac{\frac{\pi}{4}d^3}{25\times15\times5} = 0.5 \Rightarrow d = 10.6 \text{ cm}$$

Hence, the correct answer is 10.5 to 10.7.

Question Number: 37 **Question Type: MCQ**

For the linear programming problem:

$$\text{Maximize } Z = 3X_1 + 2X_2$$

Subject to

$$-2X_1 + 3X_2 \le 9$$
$$X_1 - 5X_2 \ge -20$$
$$X_1, X_2 \ge 0$$

The above problem has

(A) unbounded solution
(B) infeasible solution
(C) alternative optimum solution
(D) degenerate solution

Solution: Maximum $Z = 3x_1 + 2x_2$

Subject to $-2x_1 + 3x_2 \le 9$

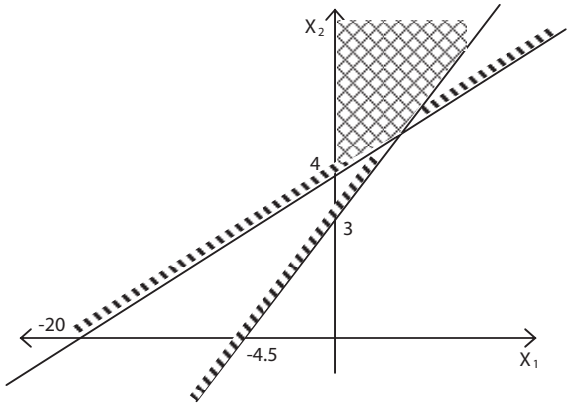
$$x_1 - 5x_2 \ge -20$$
$$x_1, x_2 \ge 0$$

the constraints are,

$$-2x_1 + 3x_2 \le 9 \quad (1)$$
$$-x_1 + 5x_2 \le 20 \quad (2)$$

From Eq. (1), $\frac{x_1}{-4.5} + \frac{x_2}{3} \le 1$

From Eq. (2) $\frac{x_1}{-20} + \frac{x_2}{4} \le 1$



The shaded region represents the solution of the given problem which is unbounded.

Hence, the correct option is (A).

Question Number: 38 **Question Type: MCQ**

Which of the following statements are TRUE, when the cavitation parameter $\sigma = 0$?

(i) the local pressure is reduced to vapor pressure
(ii) cavitation starts

(iii) boiling of liquid starts

(iv) cavitation stops

(A) (i), (ii), and (iv) (B) only (ii) and (iii)
(C) only (i) and (iii) (D) (i), (ii), and (iii)

Solution: When cavitation parameter, $\sigma = 0$, then $P \leq P_{vapor}$

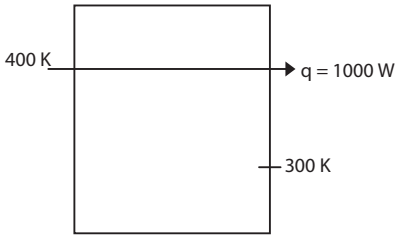
At this local pressure (less than or equal to vapour pressure), cavitation and boiling of liquid starts.

Hence, the correct option is (D).

Question Number: 39 **Question Type: NAT**

One side of a wall is maintained at 400 K and the other at 300 K. The rate of heat transfer through the wall is 1000 W and the surrounding temperature is 25°C. Assuming no generation of heat within the wall, the irreversibility (in W) due to heat transfer through the wall is _____.

Solution:



Irreversibility, $I = T_o(\triangle S)_{universe}$

$\Rightarrow \quad I = T_o(\triangle S_{sys} + \triangle S_{surr})$

$\Rightarrow \quad I = (25 + 273)\left[-\frac{1000}{400} + \frac{1000}{300}\right] \Rightarrow I = 248.34 \text{ W}$

Hence, the correct answer is 247 to 249.

Question Number: 40 **Question Type: MCQ**

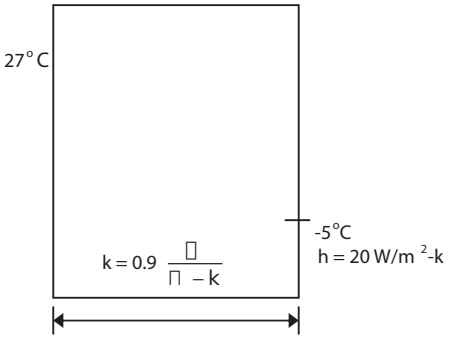
A brick wall $\left(k = 0.9\frac{W}{m.K}\right)$ of thickness 0.18 m separates the warm air in a room from the cold ambient air. On a particular winter day, the outside air temperature is –5°C and the room needs to be maintained at 27°C. The heat transfer coefficient associated with outside air is $20\frac{W}{m^2 K}$.

Neglecting the convective resistance of the air inside the room, the heat loss, in $\left(\frac{W}{m^2}\right)$, is

(A) 88 (B) 110
(C) 128 (D) 160

Solution:

$$Q = \frac{\Delta T}{\frac{L}{kA} + \frac{1}{hA}} = \frac{Q}{A} = \frac{\Delta T}{\left[\frac{L}{k} + \frac{1}{h}\right]}$$



$$\Rightarrow \frac{Q}{A} = \frac{27 - (-5)}{\left[\frac{0.18}{0.9} + \frac{1}{20}\right]} = 128 \text{ W/m}^2$$

Hence, the correct option is (C).

Question Number: 41 **Question Type: NAT**

A mixture of ideal gases has the following composition by mass:

N_2	O_2	CO_2
60%	30%	10%

If the universal gas constant is 8314 J/kmol-K, the characteristic gas constant of the mixture (in J/kg-K) is _____.

Solution:

Average molar mass, $M = \frac{100}{\frac{60}{28} + \frac{30}{32} + \frac{10}{44}} \quad s = 30.233$

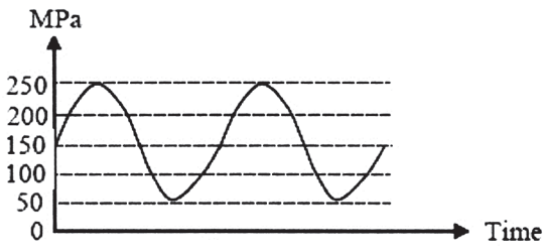
Characteristic gas constant, $R = \frac{R_o}{M} = \frac{8314}{30.233}$

$\therefore \qquad R = 274.99 \text{ J/kg–K}$

Hence, the correct answer is 274 to 276.

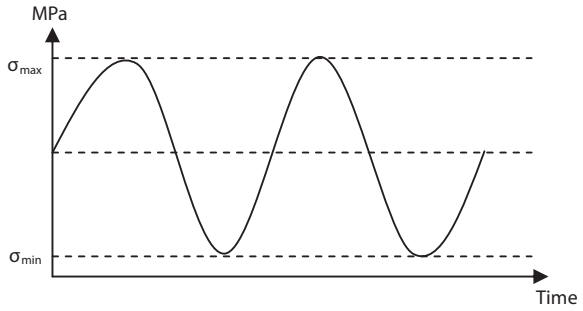
Question Number: 42 **Question Type: MCQ**

For the given fluctuating fatigue load, the values of stress amplitude and stress ratio are respectively



(A) 100 MPa and 5 (B) 250 MPa and 5
(C) 100 MPa and 0.20 (D) 250 MPa and 0.20

Solution:



$$\sigma_{max} = 250 \text{ MPa}, \sigma_{min} = 50 \text{ MPa}$$

$$\text{stress amplitude} = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{250 - 50}{2} = 100 \text{ MPa}$$

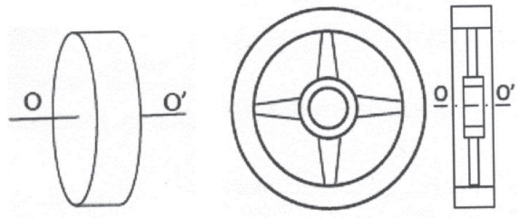
$$\text{Stress ratio} = \frac{\sigma_{min}}{\sigma_{max}} = \frac{50}{250} = 0.2$$

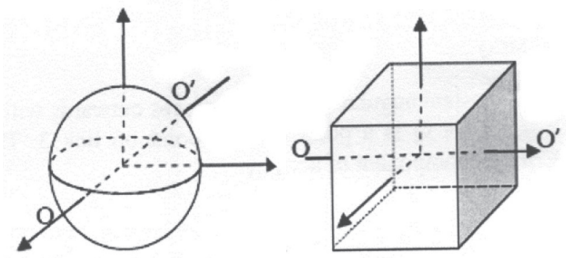
Hence, the correct option is (C).

Question Number: 43 **Question Type: MCQ**

For the same material and the mass, which of the following configurations of flywheel will have maximum mass moment of inertia about the axis of rotation OO' passing through the center of gravity.

(A) Solid cylinder (B) Rimmed wheel



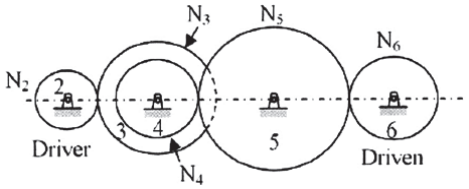


(C) Solid sphere (D) Solid cube

Solution: Mass moment of inertia is a function of mass and the radial distance from the rotating axis. In the wheel, the mass is distributed at a greater distance than the other solids. Therefore, the mass moment of inertia of the wheel is higher.

Hence, the correct option is (B).

Question Number: 44 **Question Type: MCQ**



A gear train is made up of five spur gears as shown in the figure. Gear 2 is driver and gear 6 is driven member. N_2, N_3, N_4, N_5, and N_6 represent number of teeth on gears 2, 3, 4, 5, and 6 respectively. The gear(s) which act(s) as idler(s) is/are

(A) Only 3 (B) Only 4
(C) Only 5 (D) Both 3 and 5

Solution:

$$\text{The speed ratio} = \frac{N_2}{N_6} = \frac{N_2}{N_3} \times \frac{N_3}{N_4} \times \frac{N_4}{N_5} \times \frac{N_5}{N_6} \text{ but, } N_3 = N_4$$

and $$\frac{N_2}{N_3} = \frac{T_3}{T_2}, \frac{N_4}{N_5} = \frac{T_5}{T_4}, \frac{N_5}{N_6} = \frac{T_6}{T_5}$$

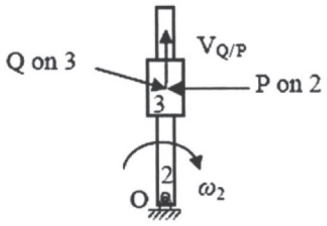
$$\therefore \frac{N_2}{N_6} = \frac{T_3}{T_2} \times \frac{T_5}{T_4} \times \frac{T_6}{T_5} = \frac{T_3 . T_6}{T_2 . T_4}$$

$\therefore$ Gear 5 does not have any effect on the speed ratio. It is an idler.

Hence, the correct option is (C).

Question Number: 45 **Question Type: MCQ**

In the figure, link 2 rotates with constant angular velocity ω_2. A slider link 3 moves outwards with a constant relative velocity $V_{Q/P}$, where Q is a point on slider 3 and P is a point on link 2. The magnitude and direction of Coriolis component of acceleration is given by



Solution: The magnitude of coriolis component of acceleration $= 2v\omega = 2\ \omega_2 . V_{Q/p}$

Direction of the coriolis component of acceleration is derived by rotating the linear velocity vector by 90° in the sense of the angular velocity. Direction of angular velocity is clockwise, by rotating the linear velocity vector $V_{Q/p}$ in

the clockwise sense by 90° the direction of coriolis acceleration is obtained.

(A) $2\omega_2 V_{Q/P}$; direction of $V_{Q/P}$ rotated by 90° in the direction of ω_2.
(B) $\omega_2 V_{Q/P}$; direction of $V_{Q/P}$ rotated by 90° in the direction of ω_2.
(C) $2\omega_2 V_{Q/P}$; direction of $V_{Q/P}$ rotated by 90° opposite to the direction of ω_2.
(D) $\omega_2 V_{Q/P}$; direction of $V_{Q/P}$ rotated by 90° opposite of ω_2.

Hence, the correct option is (A).

Question Number: 46 **Question Type: MCQ**

The strain hardening exponent n of stainless steel SS 304 with distinct yield and UTS values undergoing plastic deformation is

(A) $n < 0$ (B) $n = 0$
(C) $0 < n < 1$ (D) $n = 1$

Solution: Strain hardening exponent (n) is a material constant. The value of n lies in between 0 and 1.

0 means it's a perfectly plastic material.

1 means it's a perfectly elastic material.

Stainless steel 304 has a n value of 0.44.

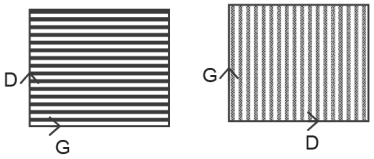
Hence, the correct option is (C).

Question Number: 47 **Question Type: MCQ**

In a machining operation, if the generatrix and directrix both are straight lines, the surface obtained is

(A) cylindrical (B) helical
(C) plane (D) surface of revolution

Solution: The generation of flat surfaces is done by traversing a straight line (Generatrix) G, in a perpendicular direction (Directrix) D as shown in the figure.



Hence, the correct option is (C).

Question Number: 48 **Question Type: MCQ**

In full mould (cavity-less) casting process, the pattern is made of

(A) expanded polystyrene (B) wax
(C) epoxy (D) plaster of Paris

Solution: Full mould process also called the lost foam process uses a pattern with the complete gates and risers. The pattern material used is expanded polystyrene (EPS).

The molten metal gasifies the pattern, progressive displacement of the pattern material takes place.

Hence, the correct option is (A).

Question Number: 49 **Question Type: MCQ**

In the notation (a/b/c):(d/e/f) for summarizing the characteristics of queueing situation, the letters 'b' and 'd' stand respectively for

(A) service time distribution and queue discipline
(B) number of servers and size of calling source
(C) number of servers and queue discipline
(D) service time distribution and maximum number allowed in system.

Solution: Kendall's notation

(a/b/c):(d/e/f)

a & b: arrival and service distributions respectively.
c: No. of service channels
d: Service discipline
e: Maximum no. of customers allowed
f: Population

Hence, the correct option is (A).

Question Number: 50 **Question Type: MCQ**

Couette flow is characterized by

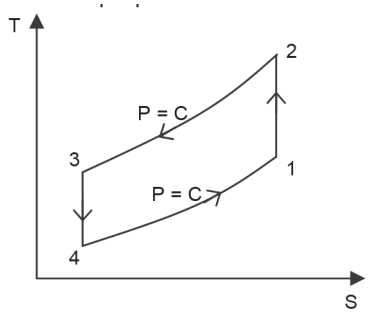
(A) steady, incompressible, laminar flow through a straight circular pipe.
(B) fully developed turbulent flow through a straight circular pipe.
(C) steady, incompressible, laminar flow between two fixed parallel plates.
(D) steady, incompressible, laminar flow between one fixed plate and the other moving with a constant velocity.

Solution: Couette flow is characterized by steady, in compressible, laminar flow between one fixed plate and the other moving with constant velocity.

Hence, the correct option is (D).

Question Number: 51 **Question Type: MCQ**

The thermodynamic cycle shown in the figure (T-s diagram) indicates

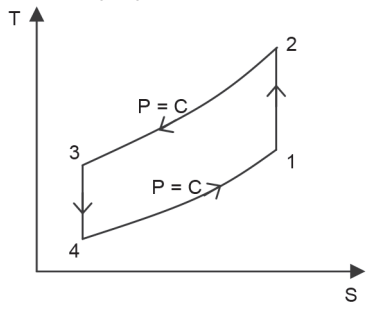


(A) reversed Carnot cycle
(B) reversed Brayton cycle
(C) vapor compression cycle
(D) vapor absorption cycle

Solution:

Brayton Cycle:

Two isentropic processes and two constant pressure processes.



Anticlockwise cycle. Hence, it is a reverse Brayton cycle.

Hence, the correct option is (B).

Question Number: 52 **Question Type: MCQ**

The ratio of momentum diffusivity (v) to thermal diffusivity (a), is called

(A) Prandtl number (B) Nusselt number
(C) Biot number (D) Lewis number

Solution:

$$\text{Prandtl number, } P_r = \frac{\text{Momentum diffusivity}}{\text{Thermal diffusivity}}$$

$$\Rightarrow P_r = \frac{\vartheta}{\propto} = \frac{\mu C_P}{k}$$

Hence, the correct option is (A).

Question Number: 53 **Question Type: MCQ**

Saturated vapor is condensed to saturated liquid in a condenser. The heat capacity ratio if $C_r = \frac{C_{min}}{C_{max}}$. The effectiveness ($\varepsilon$) of the condenser is

(A) $\dfrac{1-\exp\left[-NTU\left(1+C_r\right)\right]}{1+C_r}$

(B) $\dfrac{1-\exp\left[-NTU\left(1-C_r\right)\right]}{1-C_r\exp\left[-NTU\left(1-C_r\right)\right]}$

(C) $\dfrac{NTU}{1+NTU}$

(D) $1 - \exp(-NTU)$

Solution: Throughout condenser, the hot fluid (steam) remains at constant temperature. Hence, C_{max} is ∞ and C_{min} is for cold fluid.

$$\therefore \frac{C_{min}}{C_{max}} = 0$$

For parallel flow $\rightarrow \varepsilon = \dfrac{1-\exp\left[-NTU\left\{1-C_{min}/C_{max}\right\}\right]}{1+\left[C_{min}/C_{max}\right]}$

For counter flow $\rightarrow$

$$\varepsilon = \frac{1-\exp\left[-NTU\left\{1-C_{min}/C_{max}\right\}\right]}{1-\left\{C_{min}/C_{max}\right\}\exp\left[-NTU\left\{1-C_{min}/C_{max}\right\}\right]}$$

$$\therefore \text{ For } \frac{C_{min}}{C_{max}} = 0,\ \varepsilon = 1 - \exp(-\text{NTU})$$

Hence, the correct option is (D).

Question Number: 54 **Question Type: NAT**

Using a unit step size, the value of integral $\int_1^2 x \ln x\, dx$ by trapezoidal rule is _____.

Solution: Here step size $= h = 1$, $a = 1$, $b = 2$

$$\therefore \quad n = \frac{b-a}{h} = \frac{2-1}{1} = 1$$

Let

$y = f(x) = x \ln x$		
x	1	2
$f(x)$	0	1.3863

By trapezoidal rule, we have

$$\int_1^2 x \ln x dx = \frac{h}{2}\left[f(1) + f(2)\right]$$

$$= \frac{1}{2}\left[0 + 1.3863\right] = 0.6931.$$

Hence, the correct answer is 0.68 to 0.70.

Question Number: 55 **Question Type: MCQ**

If $P(X) = 1/4$, $P(Y) = 1/3$, and $P(X \cap Y) = 1/12$, the value of $P(Y/X)$ is

(A) $\frac{1}{4}$ (B) $\frac{4}{25}$

(C) $\frac{1}{3}$ (D) $\frac{29}{50}$

Solution:

Given $P(X) = \frac{1}{4}$, $P(Y) = \frac{1}{3}$, and $P(X \cap Y) = \frac{1}{12}$

$$\therefore \quad P\left(\frac{Y}{X}\right) = \frac{P(X \cap Y)}{P(X)} = \frac{\left(\frac{1}{12}\right)}{\left(\frac{1}{4}\right)} = \frac{1}{3}.$$

Hence, the correct option is (C).

Question Number: 56 **Question Type: NAT**

The lowest Eigen value of the 2×2 matrix $\begin{bmatrix} 4 & 2 \\ 1 & 3 \end{bmatrix}$ is _____.

Solution: Let $A = \begin{bmatrix} 4 & 2 \\ 1 & 3 \end{bmatrix}$

The characteristic equation of A is $|A - \lambda I| = 0$

$$\Rightarrow \quad \begin{vmatrix} 4-\lambda & 2 \\ 1 & 3-\lambda \end{vmatrix} = 0$$

$$\Rightarrow \quad (4 - \lambda)(3 - \lambda) - 2 = 0$$

$$\Rightarrow \quad \lambda^2 - 7\lambda + 10 = 0$$

$$\Rightarrow \quad (\lambda - 2)(\lambda - 5) = 0$$

$$\Rightarrow \quad \lambda = 2 \text{ and } \lambda = 5$$

The lowest eigen value of A is 2.

Hence, the correct answer is 2.

Question Number: 57 **Question Type: NAT**

The value of $\lim_{x \to 0}\left(\frac{-\sin x}{2\sin x + x\cos x}\right)$ is _____.

Solution: We have $\lim_{x \to 0}\left(\frac{-\sin x}{2\sin x + x\cos x}\right)$

$$= \lim_{x \to 0}\left(\frac{-\cos x}{2\cos x + \cos x - x\sin x}\right)$$

(By L' Hospital's rule)

$$= \lim_{x \to 0}\left(\frac{-\cos x}{3\cos x - x\sin x}\right) = \frac{-1}{3} = -0.33.$$

Hence, the correct answer is –0.35 to –0.30.

Question Number: 58 **Question Type: NAT**

A cylindrical tank with closed ends is filled with compressed air at a pressure of 500 kPa. The inner radius of the tank is 2 m, and it has wall thickness of 10 mm. The magnitude of maximum inplane shear stress (in MPa) is _____.

Solution:

Given: $P = 500$ kPa, $D = 4$ m, $t = 0.01$ m

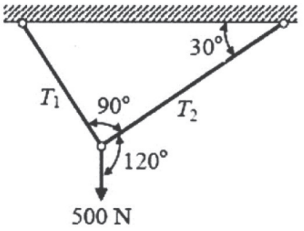
Maximum inplane shear stress, $\tau_{max} = \frac{PD}{8t}$

$$\Rightarrow \tau_{max} = \frac{500 \times 4}{8 \times 0.01} \Rightarrow \tau_{max} = 25 \text{ MPa}.$$

Hence, the correct answer is 25.

Question Number: 59 **Question Type: MCQ**

A weight of 500 N is supported by two metallic ropes as shown in the figure. The values of tensions T_1 and T_2 are respectively



(A) 433 N and 250 N (B) 250 N and 433 N
(C) 353.5 N and 250 N (D) 250 N and 353.5 N

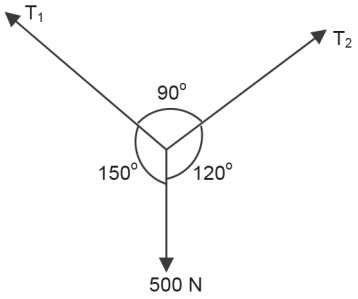
Solution:

$$\frac{T_2}{\sin 150^o} = \frac{T_1}{\sin 120^o} = \frac{500}{\sin 90^o}$$

$$\Rightarrow \quad T_1 = 500 \times \sin 120^o$$

$$\Rightarrow \quad T_1 = 433 \text{ N and } T_2 = 500 \times \sin 150^o$$

$$\therefore \quad T_2 = 250 \text{ N}$$



Hence, the correct option is (A).

Question Number: 60 **Question Type: MCQ**

Which of the following statements are TRUE for damped vibrations?

(P) For a system having critical damping, the value of damping ratio is unity and system does not undergo a vibratory motion.
(Q) Logarithmic decrement method is used to determine the amount of damping in a physical system.
(R) In case of damping due to dry friction between moving surfaces, resisting forces of constant magnitude act opposite to the relative motion.

(S) For the case of viscous damping, drag force is directly proportional to the square of relative velocity.

(A) P and Q only (B) P and S only
(C) P, Q, and R only (D) Q and S only

Solution: Critical damping brings the system to the position of rest in the shortest possible time without any oscillations.

Logarithmic decrement is given by $\delta = \dfrac{2\pi\xi}{\sqrt{1-\xi^2}}$

It depends only on damping ratio.

Frictional force is in the opposite direction of the relative motion and is given by $F = \mu R$,

where R is the resisting force.

In an viscous damping system with laminar flow, piston rod with small diameter, perfect fluid, laminar flow in the clearance and piston and cylinder being concentric the damping coefficient, is given by

$$C = \frac{12\mu}{\pi} \cdot \frac{A_P\, l}{D_m\, e^3}$$

μ = coefficient of viscosity of the fluid

e = clearance

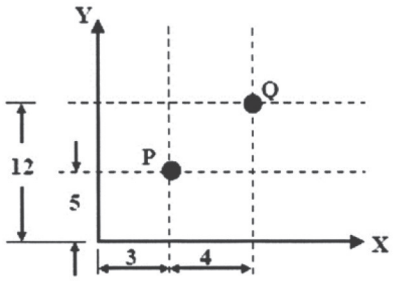
l = length of piston

A_P = area of flat side of the piston

Hence, the correct option is (C).

Question Number: 61 **Question Type: MCQ**

A drill is positioned at point P and it has to proceed to point Q. The coordinates of point Q in the incremental system of defining position of a point in *CNC* part program will be



(A) (3, 12) (B) (5, 7)
(C) (7, 12) (D) (4, 7)

Solution: The point $P(3, 5)$ is considered as origin and the coordinates of point $Q(7, 12)$ WRT the new origin is

$Q = (7, 12) - (3, 5) = ([7 - 3], (12 - 5])$

$Q = (4, 7)$

Hence, the correct option is (D).

Question Number: 62 **Question Type: MCQ**

Which two of the following joining processes are autogeneous?

(i) Diffusion welding

(ii) Electroslag welding

(iii) Tungsten inert gas welding

(iv) Friction welding

(A) (i) and (iv) (B) (ii) and (iii)
(C) (ii) and (iv) (D) (i) and (iii)

Solution: Autogeneous processes do not have a filler material. In tungsten inert gas welding and electroslag welding filler material is provided.

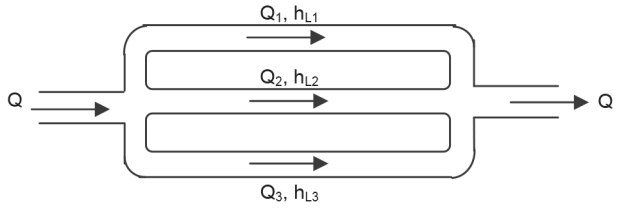
Hence, the correct option is (A).

Question Number: 63 **Question Type: MCQ**

Three parallel pipes connected at the two ends have flow-rates Q_1, Q_2, and Q_3, respectively, and the corresponding frictional head losses are h_{L1}, h_{L2}, and h_{L3} respectively. The correct expressions for total flow rate (Q) and frictional head loss across the two ends (h_L) are

(A) $Q = Q_1 + Q_2 + Q_3;\ h_L = h_{L1} + h_{L2} + h_{L3}$
(B) $Q = Q_1 + Q_2 + Q_3;\ h_L = h_{L1} = h_{L2} = h_{L3}$
(C) $Q = Q_1 = Q_2 = Q_3;\ h_L = h_{L1} + h_{L2} + h_{L3}$
(D) $Q = Q_1 = Q_2 = Q_3;\ h_L = h_{L1} = h_{L2} = h_{L3}$

Solution:



Total flow rate, $Q = Q_1 + Q_2 + Q_3$ and frictional head loss,

$$h_{L_1} = h_{L_2} = h_{L_3} = \frac{fLV^2}{2yD}$$

Hence, the correct option is (B).

Question Number: 64 **Question Type: MCQ**

A rigid container of volume 0.5 m^3 contains 1.0 kg of water at 120°C (v_f = 0.00106 m^3/kg, v_g = 0.8908 m^3/kg). The state of water is

(A) compressed liquid
(B) saturated liquid
(C) a mixture of saturated liquid and saturated vapor
(D) superheated vapor

Solution: $V_1 = 0.5$ m^3, $m = 1$ kg, $\theta_f = 0.00106$ m^3/kg,

$\theta_g = 0.8908$ m^3/kg

$$\theta_1 = \frac{V_1}{m} = \frac{0.5}{1} = \theta_f + x\,\theta_{fg}$$

$$\Rightarrow \quad 0.5 = 0.00106 + x(0.8908 - 0.00106)$$

$$\Rightarrow \quad x = 0.56$$

Since dryness fraction, $x < 1$, the state of water is a mixture of saturated liquid and saturated vapor.

Hence, the correct option is (C).

Question Number: 65 **Question Type: MCQ**

Let ϕ be an arbitrary smooth real-valued scalar function and $\vec{V}$ be an arbitrary smooth vector valued function in three-dimensional space. Which one of the following is an identity?

(A) $\text{Curl}(\phi \vec{V}) = \nabla (\phi \text{ Div} \vec{V})$

(B) $\text{Div} \vec{V} = 0$

(C) $\text{Div Curl} \vec{V} = 0$

(D) $\text{Div}(\phi \vec{V}) = \phi \text{ Div} \vec{V}$

Solution: For any smooth vector-valued function $\overline{V}$, Div curl $\overline{V} = 0$.

Hence, the correct option is (C).

GATE 2015 Solved Paper
ME: Mechanical Engineering
Set – 2

Number of Questions: 65 **Total Marks:100.0**

Wrong answer for MCQ will result in negative marks, (−1/3) for 1 Mark Questions and (−2/3) for 2 Marks Questions.

General Aptitude

Number of Questions: 10 **Section Marks: 15.0**

Q.1 to Q.5 carry 1 mark each and Q.6 to Q.10 carry 2 marks each.

Question Number: 1 **Question Type: MCQ**

In the following sentence, certain parts are underlined and marked *P*, *Q,* and *R*. One of the parts may contain certain error or may not be acceptable in standard written communication. Select the part containing an error. Choose D as your answer if there is no error.

The student corrected all the errors that
P
the instructor marked on the answer book.
Q *R*

(A) *P* (B) *Q*
(C) *R* (D) No error

Solution: The sentence shows a sequence of events and, hence, it should be in the past perfect tense. The underlined section Q is incorrect. It should be 'had marked' as it helps to show an activity which was done after another activity.

Hence, the correct option is (B).

Question Number: 2 **Question Type: MCQ**

Given below are two statements followed by two conclusions. Assuming these statements to be true, decide which one logically follows.

Statements:

I. All film stars are playback singers.

II. All film directors are film stars.

Conclusions:

I. All film directors are playback singers.

II. Some film stars are film directors.

(A) Only conclusion I follows.
(B) Only conclusion II follows.
(C) Neither conclusion I nor II follows.
(D) Both conclusions I and II follow.

Solution: All film starts are playback singers

All Film directors are film stars

Both the given previews are universal affirmative. Then the conclusion has to be universal affirmative or particular affirmative.

✓ ×

Premises : All film stars are playback singers

✓ ×

All film directors are film stars

✓ ×

Conclusion : All film directors are playback singers

✓ – Distributed × – Not Distributed

So the above conclusion complies with all the rules. Thus, All film directors are playback singers is a valid conclusion.

Some Film stars are Film directors.

In this statement both subject and predicate are not distributed. But it satisfies the following rule as well.

If a term is distributed in the conclusion, then it should be distributed in the premise also. Thus, both conclusions follow.

Hence, the correct option is (D).

Question Number: 3 **Question Type: NAT**

A tiger is 50 leaps of its own behind a deer. The tiger takes 5 leaps per minute to the deer's 4. If the tiger and the deer cover 8 meter and 5 meter per leap respectively, what distance in meters will the tiger have to run before it catches the deer?

Solution: Lengths of each leap of the tiger and the deer are 8 m and 5 m, respectively.

The tiger is 50 leaps of its own behind the deer

$\therefore$ It is 400 m behind the deer.

Time taken for the tiger to catch the deer (T)

$$= \frac{400}{\text{Relative speed}(R)}$$

The tiger takes 5 leaps per minute and the deer takes 4 leaps per minute.

$\therefore$ The speeds of the tiger and the deer are (5) (8) m per minute and 4 (5) m per minute respectively i.e. 40 m per minute and 20 m per minute respectively.

Time taken by figure to catch up with deer (in min)

$$= \frac{400}{40-20} = 20$$

Distance that the tiger will have to run before it catches the deer = 20 (40) i.e. 800 m

Hence, the correct answer is 800.

Question Number: 4 **Question Type: MCQ**

If $a^2 + b^2 + c^2 = 1$, then $ab + bc + ac$ lies in the interval

(A) [1, 2/3] (B) [–1/2, 1]
(C) [–1, 1/2] (D) [2, –4]

Solution: Given,

$$a^2 + b^2 + c^2 = 1$$

$$(a + b + c)^2 \geq 0$$

$$a^2 + b^2 + c^2 + 2\,(ab + bc + ca) \geq 0$$

i.e., $$1 + 2\,(ab + bc + ca) \geq 0.$$

$$ab + bc + ca \geq -\frac{1}{2}$$

Also, $(a-b)^2 + (b-c)^2 + (c-a)^2 \geq 0.$

$\therefore$ $a^2 + b^2 + c^2 \geq ab + bc + ca$

$ab + bc + ca$ lies in the interval $\left[\frac{-1}{2}, 1\right]$

Hence, the correct option is (B).

Question Number: 5 **Question Type: MCQ**

Lamenting the gradual sidelining of the arts in school curricula, a group of prominent artists wrote to the Chief Minister last year, asking him to allocate more funds to support arts education in schools. However, no such increase has been announced in this year's Budget. The artists expressed their deep anguish at their request not being approved, but many of them remain optimistic about funding in the future.

Which of the statement(s) below is/are logically valid and can be inferred from the above statements?

(i) The artists expected funding for the arts to increase this year.
(ii) The Chief Minister was receptive to the idea of increasing funding for the arts.
(iii) The Chief Minister is a prominent artist.
(iv) Schools are giving less importance to arts education nowadays.

(A) (iii) and (iv) (B) (i) and (iv)
(C) (i), (ii), and (iv) (D) (i) and (iii)

Solution: From the above passage, we can infer that schools are giving less importance to arts education these days and the artists are hoping that the funding for arts will increase this year. These two points are very much clear from statements i and iv; thus choice (B) is the answer.

Hence, the correct option is (B).

Question Number: 6 **Question Type: MCQ**

Choose the appropriate word/phrase, out of the four options given below, to complete the following sentence:

Dhoni, as well as the other team members of Indian team, _____ present on the occasion.

(A) were (B) was
(C) has (D) have

Solution: As 'Dhoni' a singular noun is the main subject of the sentence, the verb should also be singular. This makes option (B) correct.

Hence, the correct option is (B).

Question Number: 7 **Question Type: MCQ**

Choose the word most similar in meaning to the given word:

Awkward

(A) Inept (B) Graceful
(C) Suitable (D) Dreadful

Solution: 'Awkward' means 'lacking skill', which is similar in meaning to 'inept'. 'Graceful' is the opposite of 'awkward'. 'Suitable' means 'something that is right or correct for something or for a situation'. 'Dreadful' means 'very bad or unpleasant'.

Hence, the correct option is (A).

Question Number: 8 **Question Type: MCQ**

What is the adverb for the given word below?

Misogynous

(A) Misogynousness (B) Misogynity
(C) Misogynously (D) Misogynous

Solution: The adverb of most words end in an 'sly' form. Hence, choice (C) and not choice (B) is correct.

Hence, the correct option is (C).

Question Number: 9 **Question Type: MCQ**

An electric bus has onboard instruments that report the total electricity consumed since the start of the trip as well as the total distance covered. During a single day of operation, the bus travels on stretches *M*, *N*, *Q,* and *P*, in that order. The cumulative distances traveled and the corresponding electricity consumption are shown in the table below:

Stretch	Cumulative distance (km)	Electricity used (kWh)
M	20	12

N	45	25
O	75	45
P	100	57

The stretch where the electricity consumption per km is minimum is

(A) *M* (B) *N*
(C) *O* (D) *P*

Solution: Electricity consumption per km

$$= \frac{\text{Electricity used}}{\text{Distance traveled (in km)}}$$

The electricity consumptions per km over the stretches *M*, *N*, *O*, *P* are $\frac{12}{20}, \frac{25-12}{45-20}, \frac{45-25}{75-45}, \frac{57-45}{100-75}$ respectively i.e. 0.6, 0.52, 0.6, 0.48, respectively.

The stretch where the electricity consumption per km is minimum is *P*.

Hence, the correct option is (D).

Question Number: 10 **Question Type: MCQ**

Ram and Ramesh appeared in an interview for two vacancies in the same department. The probability of Ram's selection is 1/6 and that of Ramesh is 1/8. What is the probability that only one of them will be selected?

(A) 47/48 (B) 1/4
(C) 13/48 (D) 35/48

Solution: *P* (only are of Ram and Ramesh being selected)

$$= P(\text{Ram}) \times P\left(\overline{\text{Ramesh}}\right) + P\left(\overline{\text{Ram}}\right) \times P(\text{Ramesh})$$

$$= \frac{1}{6} \times \left(1 - \frac{1}{8}\right) + \left(1 - \frac{1}{6}\right) \times \frac{1}{8} = \frac{7}{48} + \frac{5}{48} = \frac{1}{4}.$$

Hence, the correct option is (B).

Mechanical Engineering

Number of Questions: 55 **Section marks: 85.0**

Q.11 to Q.35 carry 1 mark each and Q.36 to Q.65 carry 2 marks each.

Question Number: 11 **Question Type: MCQ**

The function of interpolator in a CNC machine controller is to

(A) control spindle speed
(B) coordinate feed rates of axes
(C) control tool rapid approach speed
(D) perform miscellaneous (*M*) functions (tool change, coolant control, etc.)

Solution: Interpolator is a control system used for linear, circular, parabolic, and cubic interpolation in CNC machine. This tool/workpiece is made to move by making small increments between the prescribed points.

Hence, the correct option is (B).

Question Number: 12 **Question Type: NAT**

Consider a spatial curve in three-dimensional space given in parametric form by

$$x(t) = \cos t, y(t) = \sin t, z(t) = \frac{2}{\pi} t, 0 \le t \le \frac{\pi}{2}$$

The length of the curve is _____.

Solution: Given curve in parametric form is $x = \cos t, y = \sin t, z = \frac{2}{\pi} t$

$$\Rightarrow \quad \frac{dx}{dt} = -\sin t, \ \frac{dy}{dt} = \cos t, \text{ and } \frac{dz}{dt} = \frac{2}{\pi}$$

The length of the curve for $0 \le t \le \frac{\pi}{2}$ is length

$$= \int_{t=0}^{\frac{\pi}{2}} \sqrt{\left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2\right]} dt$$

$$= \int_{0}^{\frac{\pi}{2}} \sqrt{\left[(-\sin t)^2 + (\cos t)^2 + \left(\frac{2}{\pi}\right)^2\right]} dt$$

$$= \int_{0}^{\frac{\pi}{2}} \sqrt{\left[\sin^2 t + \cos^2 t + \frac{4}{\pi^2}\right]} dt$$

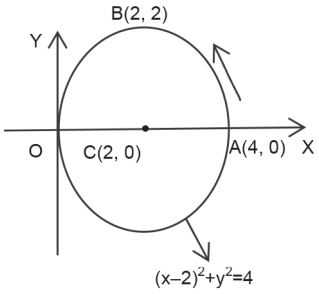
$$= \left(\sqrt{1 + \frac{4}{\pi^2}}\right) t \Big]_0^{\frac{\pi}{2}} \Rightarrow = \left(\sqrt{1 + \frac{4}{\pi^2}}\right) \frac{\pi}{2}$$

$$= \left[\sqrt{\frac{\pi^2}{4}\left(1 + \frac{4}{\pi^2}\right)} \Rightarrow = \sqrt{\left(\frac{\pi^2}{4} + 1\right)} = 1.8614.\right.$$

Hence, the correct answer is 1.85 to 1.87.

Question Number: 13 **Question Type: NAT**

Consider an ant crawling along the curve $(x-2)^2 + y^2 = 4$, where *x* and *y* are in meters. The ant starts at the point (4, 0) and moves counter-clockwise with a speed of 1.57 meters per second. The time taken by the ant to reach the point (2, 2) is (in seconds) _____.



Solution: The distance traveled by the particle in moving from (4, 0) to (2, 2) $= AB = \frac{1}{4} \times$ circumference of the circle

$$= \frac{1}{4} \times 2\pi \times 2 = \pi \text{ meters}$$

Given speed of ant = 1.57 meters/second

$\therefore$ Time taken by the ant to reach the point $B(2, 2)$ from the point $A(4, 0)$

$$= \frac{\text{Distance}}{\text{Speed}} = \frac{\pi}{1.57} = \frac{3.14}{1.57} = 2 \text{ sec.}$$

Hence, the correct answer is 1.9 to 2.1.

Question Number: 14 **Question Type: MCQ**

Find the solution of $\frac{d^2y}{dx^2} = y$ which passes through the origin and the point $\left(\ln 2, \frac{3}{4}\right)$

(A) $y = \frac{1}{2}e^x - e^{-x}$ (B) $y = \frac{1}{2}(e^x + e^{-x})$

(C) $y = \frac{1}{2}(e^x - e^{-x})$ (D) $y = \frac{1}{2}e^x + e^{-x}$

Solution: Given differential equation is

$$\frac{d^2y}{dx^2} = y \tag{1}$$

$$\Rightarrow \quad \frac{d^2y}{dx^2} - y = 0$$

The auxiliary equation of (1) is

$$D^2 - 1 = 0$$

$$\Rightarrow \quad D = \pm 1$$

The general solution of Eq. (1) is

$$y = c_1 e^x + c_2 e^{-x} \tag{2}$$

Given Eq. (2) passes through the origin (0, 0)

i.e., $y(0) = 0$

From Eq. (2)

$$c_1 + c_2 = 0 \tag{3}$$

Given Eq. (2) passes through the point $\left(\ln 2, \frac{3}{4}\right)$

i.e. $y(\ln 2) = \frac{3}{4}$

From Eq. (2), $c_1 e^{\ln 2} + c_2 e^{-(\ln 2)} = \frac{3}{4}$

$$\Rightarrow \quad 2c_1 + \frac{1}{2}c_2 = \frac{3}{4}$$

$$\Rightarrow \quad 2c_1 + \frac{1}{2}(-c_1) = \frac{3}{4} \qquad \text{(From Eq. (1), } c_2 = -c_1\text{)}$$

$$\Rightarrow \quad \frac{3}{2}c_1 = \frac{3}{4}$$

$$\Rightarrow \quad c_1 = \frac{1}{2}$$

$$\Rightarrow \quad c_2 = -c_1 = \frac{-1}{2}$$

Substituting the values of c_1 and c_2 in Eq. (2), we get the required solution of Eq. (1) as

$$y = \frac{1}{2}e^x + \left(\frac{-1}{2}\right)e^{-x}$$

$$\Rightarrow \quad y = \frac{1}{2}(e^x - e^{-x}).$$

Hence, the correct option is (C).

Question Number: 15 **Question Type: MCQ**

The probability of obtaining at least two 'SIX' in throwing a fair dice 4 times is

(A) 425/432 (B) 19/144

(C) 13/144 (D) 125/432

Solution: Throwing a fair dice 4 times can be considered as a binomial experiment with

'Getting "SIX" on the dice' as success

$\therefore \quad p = \frac{1}{6}$ and $q = \frac{5}{6}$

Probability of getting 'SIX' at least two times

$$= P(X \geq 2) = 1 - P(X < 2)$$

$$= 1 - [P(X = 0) + P(X = 1)]$$

$$= 1 - \left[{}^4C_0\left(\frac{1}{6}\right)^0\left(\frac{5}{6}\right)^4 + {}^4C_1\left(\frac{1}{6}\right)^1\left(\frac{5}{6}\right)^3\right]$$

$$= 1 - \frac{125}{144} = \frac{19}{144}.$$

Hence, the correct option is (B).

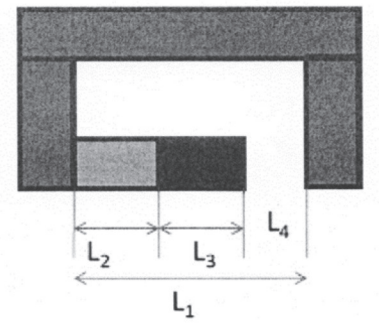
Question Number: 16 **Question Type: MCQ**

In the assembly shown below, the part dimensions are:

$L_1 = 22.0 \pm 0.01$ mm,

$L_2 = L_3 = 10.0 \pm 0.005$ mm.

Assuming the normal distribution of part dimensions, the dimension L_4 in mm for assembly condition would be:



(A) 2.0 ± 0.008 (B) 2.0 ± 0.012

(C) 2.0 ± 0.016 (D) 2.0 ± 0.020

Solution: Basic size of $L_4 = L_1 - (L_2 + L_3)$

$= 22^{+0.01}_{-0.01} - \left(10^{+0.005}_{-0.005} + 10^{+0.005}_{-0.005}\right)$

$= 22^{+0.01}_{-0.01} - \left(20^{+0.01}_{-0.01}\right) = 2^{0.01-(-0.01)}_{-0.01-(+0.01)}$

$= 2^{+0.02}_{-0.02} = 2^{\pm 0.02}$

Hence, the correct option is (D).

Question Number: 17 **Question Type: NAT**

A DC welding power source has a linear voltage-current (V-I) characteristic with open circuit voltage of 80 V and a short circuit current of 300 A. For maximum arc power, the current (in Amperes) should be set as _____.

Solution: $V_0 = 80$ V and $I_S = 300$ A

$\frac{V}{V_0} + \frac{I}{I_0} = 1$ (power source characteristic)

$$\therefore \frac{V}{80} + \frac{I}{300} = 1 \Rightarrow 7.5V + 2I = 600 \Rightarrow V = \frac{1}{7.5}(600 - 2I)$$

$$P = \text{Power} = VI = \frac{1}{7.5}(600 - 2\text{I}) \cdot I$$

For maximum power, $\frac{\partial P}{\partial I} = 0$

$$\frac{\partial P}{\partial I} = \frac{1}{7.5}(600 - 4I) = 0$$

$\therefore I = 150$ Amps

Hence, the correct answer is 149 to 151.

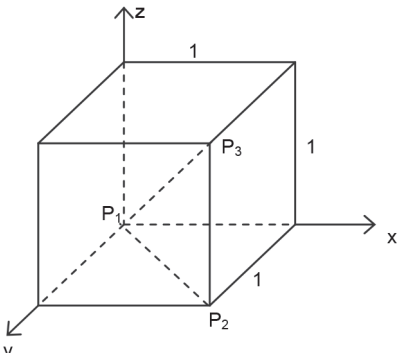
Question Number: 18 **Question Type: MCQ**

A triangular facet in a *CAD* model has vertices: $P_1(0, 0, 0)$; $P_2(1, 1, 0)$; and $P_3(1, 1, 1)$. The area of the facet is

(A) 0.500 (B) 0.707

(C) 1.414 (D) 1.732

Solution:



$P_1(0, 0, 0)$

$P_2(1, 1, 0)$

$P_3(1, 1, 1)$

In the $\triangle^{le}$ P_1, P_2, P_3,

$P_1 P_2$ is $\perp$ to $P_2 P_3$

$$\therefore \quad \text{Area} = \frac{1}{2}.(P_1 P_2).(P_2 P_3) = \frac{1}{2}.\sqrt{2}.1$$

$$= \frac{1}{\sqrt{2}} = 0.707$$

Hence, the correct option is (B).

Question Number: 19 **Question Type: MCQ**

Following data refers to the activities of a project, where, node 1 refers to the start and node 5 refers to the end of the project.

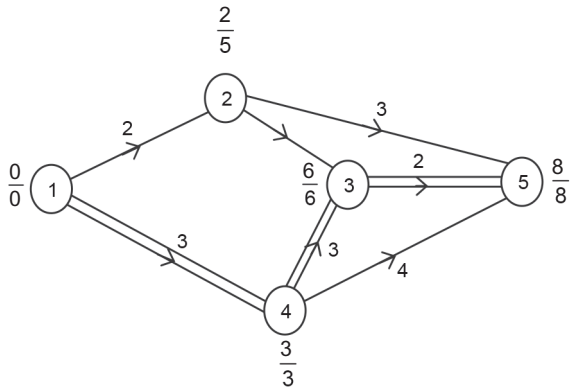
Activity	Duration (days)
1 – 2	2
2 – 3	1
4 – 3	3
1 – 4	3
2 – 5	3
3 – 5	2
4 – 5	4

The critical path (*CP*) in the network is

(A) 1-2-3-5 (B) 1-4-3-5

(C) 1-2-3-4-5 (D) 1-4-5

Solution:



Critical path: 1-4-3-5

Hence, the correct option is (B).

Question Number: 20 **Question Type: NAT**

For a canteen, the actual demand for disposable cups was 500 units in January and 600 units in February. The forecast for the month of January was 400 units. The forecast for the month of March considering smoothing coefficient as 0.75 is _____.

Solution:

Demand	Jan	Feb	Mar
Actual	500	600	
Forecast	400		

$\alpha = 0.75$

$F_{t+1} = \alpha D_t + (1-\alpha) F_t$

$\therefore \quad F_{\text{Feb}} = 0.75 \times D_{\text{Jan}} + (1 - 0.75) F_{\text{Jan}}$

$= 0.75 \times 500 + 0.25 \times 400$

$F_{\text{Feb}} = 475$

$F_{\text{Mar}} = 0.75\, D_{\text{Feb}} + 0.25\, F_{\text{Feb}}$

$= 0.75 \times 600 + 0.25 \times 475$

$F_{\text{Mar}} = 568.75$ units

Hence, the correct answer is 568 to 570.

Question Number: 21 **Question Type: NAT**

An orthogonal turning operation is carried out under the following conditions: rake angle = 5°, spindle rotational speed = 400 rpm, axial feed = 0.4 m/min, and radial depth of cut = 5 mm. The chip thickness, t_c, is found to be 3 mm. The shear angle (in degrees) in this turning process is _____.

Solution: $N = 300$ rpm, $f = 0.4$ m/min

Radial depth = 5 mm, Chip thickness, $t_c = 3$ mm

α = rake angle = 5°

In turning operation, the uncut thickness is given by

$$t = \frac{f}{N}, f \text{ in mm/min and } N \text{ in rpm}$$

$$\therefore\ t = \frac{0.4 \times 1000}{400} = 1 \text{ mm} \quad \therefore \text{Chip thickness} = \frac{t}{t_c} = \frac{1}{3}$$

Shear angle is, $\tan\varphi = \dfrac{r\cos\alpha}{1 - r\sin\alpha} = 0.342$

$\therefore\ \varphi = 18.88^\circ$

Hence, the correct answer is 18.5 to 19.

Question Number: 22 **Question Type: MCQ**

The solidification time of a casting is proportional to $\left(\frac{V}{A}\right)^2$, where V is the volume of the casting and A is the total casting surface area losing heat. Two cubes of same material and size are cast using sand casting process. The top face of one of the cubes is completely insulated. The ratio of the solidification time for the cube with top face insulated to that of the other cube is

(A) $\frac{25}{36}$ (B) $\frac{36}{25}$

(C) 1 (D) $\frac{6}{5}$

Solution: Insulated cube: $V = a^3$, $A = 5a^2$

Ratio of solidification time for insulated cube to the other

$$= \left(\frac{V}{A}\right)_I^2 : \left(\frac{V}{A}\right)^2 = \left(\frac{a^3}{5a^2}\right)^2 : \left(\frac{a^3}{6a^2}\right)^2$$

$$= \frac{a^2}{25} : \frac{a^2}{36} = 36:25$$

Hence, the correct option is (B).

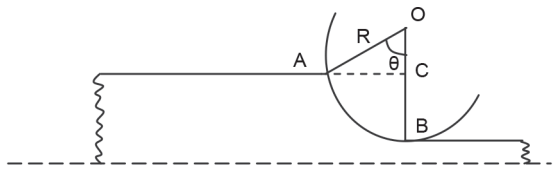
Question Number: 23 **Question Type: NAT**

In a slab rolling operation, the maximum thickness reduction ($\triangle h_{\max}$) is given by $\triangle h_{\max} = \mu^2 R$, where R is the radius of the roll and μ is the coefficient of friction between the roll and the sheet. If $\mu = 0.1$, the maximum angle subtended by the deformation zone at the center of the roll (bite angle in degrees) is _____.

Solution: θ = Angle of bite, $\mu = 0.1$

$$CB = \frac{\Delta h_{\max}}{2} = \frac{\mu^2 R}{2}$$

From $\triangle^{le}$ OAC



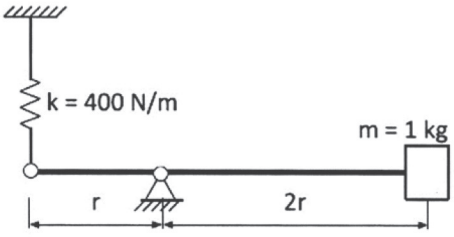
$$\cos\theta = OC/OA = \frac{OB-CB}{OA} = \frac{R-\mu^2 R/2}{R} = \frac{2-\mu^2}{2}$$

$\therefore$ $\cos\theta = 0.995 \Rightarrow \theta = 5.7317^{o}$

Hence, the correct answer is 5.6 to 5.8.

Question Number: 24 **Question Type: MCQ**

Considering massless rigid rod and small oscillations, the natural frequency (in rad/s) of vibration of the system shown in the figure is

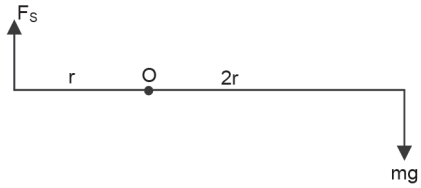


(A) $\sqrt{\frac{400}{1}}$ (B) $\sqrt{\frac{400}{2}}$

(C) $\sqrt{\frac{400}{3}}$ (D) $\sqrt{\frac{400}{4}}$

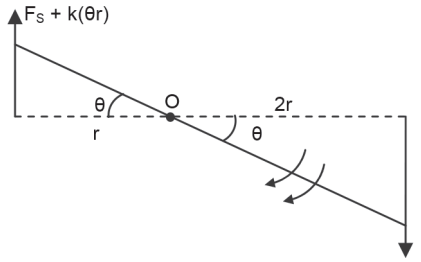
Solution:

Static Free-body Diagram



$$\Sigma M_o = 0 \Rightarrow mg(2r) + F_S(r) = 0 \qquad (1)$$

Dynamic Free-body Diagram



$$\Sigma M_o = I\left(-\ddot{\theta}\right) \Rightarrow [F_S = k(\theta r)]r + mg(2r) = I\left(-\ddot{\theta}\right)$$

$$\Rightarrow \quad F_S(r) + kr^2(\theta) + mg(2r) = I\left(-\ddot{\theta}\right)$$

From Eq. (1), $F_S(r) + mg(2r) = 0$

$$\therefore \quad I\ddot{\theta} + (kr^2)\,\theta = 0$$

$$\Rightarrow \quad m\,(2r)^2\,\ddot{\theta} + Kr^2\,\theta = 0$$

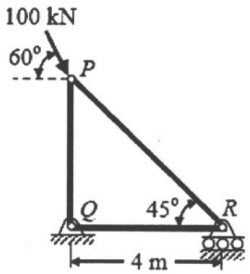
$$\Rightarrow \quad \ddot{\theta} + \left[\frac{kr^2}{m(2r)^2}\right]\theta = 0$$

Comparing with equation $\ddot{x} + \omega_n^2\, x = 0$

$$\therefore \omega_n = \sqrt{\frac{kr^2}{m \times 4r^2}} = \sqrt{\frac{400}{4}}$$

Hence, the correct option is (D).

Question Number: 25 **Question Type: MCQ**

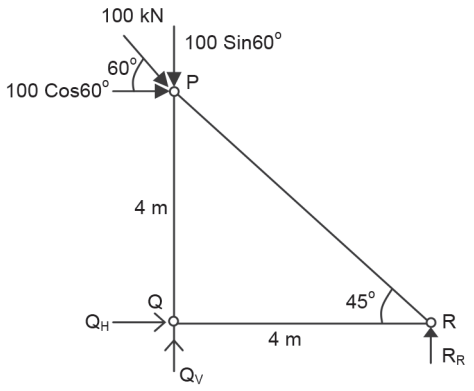


For the truss shown in the figure, the magnitude of the force in member *PR* and the support reaction at *R* are respectively

(A) 122.47 kN and 50 kN
(B) 70.71 kN and 100 kN
(C) 70.71 kN and 50 kN
(D) 81.65 kN and 100 kN

Solution:

Free-body Diagram of truss

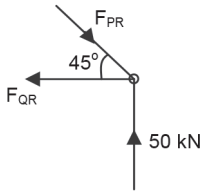


Taking moment about Q,

$$M_Q = [100 \cos 60^\circ \times 4] - [R_R \times 4] = 0$$

$\Rightarrow$ $R_R = 50$ kN [Support reaction at R]

Free-body diagram of pin at *R*



$$\Sigma F_y = 0$$

$\Rightarrow$ $F_{PR} \times \sin 45^\circ = 50 \Rightarrow F_{PR} = 70.71$ kN

[Force in member PR]

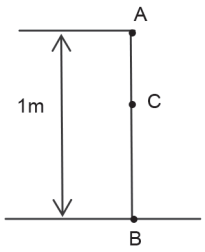
Hence, the correct option is (C).

Question Number: 26 **Question Type: NAT**

A ball of mass 0.1 kg, initially at rest, is dropped from height of 1 m. Ball hits the ground and bounces off the ground. Upon impact with the ground, the velocity reduces by 20%. The height (in m) to which the ball will rise is _____.

Solution: Energy at the height of

$$1m = mgh = 1 \times 1 \times 9.81 = 9.81 \text{ J (at } A)$$



This energy is completely converted into kinetic energy at B.

$$\therefore \frac{1}{2}mv^2 = 9.81 \Rightarrow V = \sqrt{2 \times 9.81} = 4.43 \text{ m/s}$$

20% of velocity is reduced $\Rightarrow V_B = 0.8 \times 4.43$

$$V_B = 3.543 \text{ m/s}$$

$\therefore$ The available kinetic energy after the reduction of velocity is completely converted into potential energy at point C.

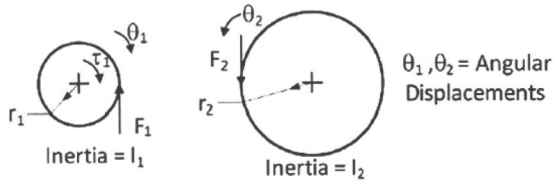
$\therefore$ $mg\, h_c = \frac{1}{2}mV_B^2$

$\therefore$ $h_C = \frac{V_B^2}{2g} = 0.64\ m$

Hence, the correct answer is 0.64.

Question Number: 27 **Question Type: MCQ**

A pinion with radius r_1, and inertia I_1 is driving a gear with radius r_2 and inertia I_2. Torque τ_1 is applied on pinion. The following are free-body diagrams of pinion and gear showing important forces (F_1 and F_2) of interaction. Which of the following relations hold true?



(A) $F_1 \neq F_2;\ \tau_1 = I_1\ \ddot{\theta}_1;\ F_2 = I_2 \frac{r_1}{r_2^2}\ddot{\theta}_1$

(B) $F_1 = F_2;\ \tau_1 = \left[I_1 + I_2\left(\frac{r_1}{r_2}\right)^2\right]\ddot{\theta}_1;\ F_2 = I_2 \frac{r_1}{r_2^2}\ddot{\theta}_1$

(C) $F_1 = F_2;\ \tau_1 = I_1\ \ddot{\theta}_1;\ F_2 = I_2 \frac{1}{r_2}\ddot{\theta}_2$

(D) $F_1 \neq F_2;\ \tau_1 = \left[I_1 + I_2\left(\frac{r_1}{r_2}\right)^2\right]\ddot{\theta}_1;\ F_2 = I_2 \frac{1}{r_2}\ddot{\theta}_2$

Solution: $F_1 = F_2$ [Same force will transmit from pinion to the gear]

$$\text{Resultant torque} = I_1\ \ddot{\theta}_1$$

$\therefore$ $\tau_1 - F_1 r_1 = I_1\ \ddot{\theta}_1$

$\Rightarrow$ $\tau_1 = I_1\ddot{\theta}_1 + F_1 r_1 \Rightarrow \tau_1 = I_1\ \ddot{\theta}_1 + F_2 r_1$ (1)

From law of gearing, $V_1 = V_2 \Rightarrow r_1\ \omega_1 = r_2\ \omega_2$ or

$$r_1\ \dot{\theta}_1 = r_2\ \dot{\theta}_2 \text{ or } \ddot{\theta}_2 = \left(\frac{r_1}{r_2}\right)\ddot{\theta}_1 \quad (2)$$

and $F_2 r_2 = I_2\ \ddot{\theta}_2 \Rightarrow F_2 = \frac{I_2}{r_2}\ \ddot{\theta}_2$

$$\Rightarrow F_2 = \frac{I_2}{r_2}\left(\frac{r_1}{r_2}\right)\ddot{\theta}_1 \quad \{\text{from Eq. (2)}\}$$

Putting the value of F_2 in Eq. (1), we get

$$\tau_1 = I_1\ \ddot{\theta}_1 + \left[\frac{I_2}{r_2}\left(\frac{r_1}{r_2}\right)\ddot{\theta}_1\right]r_1$$

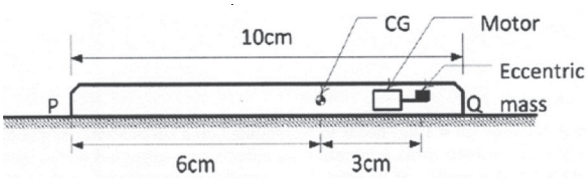
$\Rightarrow$ $\tau_1 = \left[I_1 + I_2\left(\frac{r_1}{r_2}\right)^2\right]\ddot{\theta}_1$

and $$F_2 = I_2\left(\frac{r_1}{r_2^2}\right)\ddot{\theta}_1$$

Hence, the correct option is (B).

Question Number: 28 **Question Type: MCQ**

A mobile phone has a small motor with an eccentric mass used for vibrator mode. The location of the eccentric mass on motor with respect to center of gravity (CG) of the mobile and the rest of the dimensions of the mobile phone are shown. The mobile is kept on a flat horizontal surface.



Given in addition that the eccentric mass = 2 grams, eccentricity = 2.19 mm, mass of mobile = 90 grams, $g = 9.81$ m/s^2. Uniform speed of the motor in RPM for which the mobile will get just lifted off the ground at the end Q is approximately

(A) 3000 (B) 3500
(C) 4000 (D) 4500

Solution: Free-body diagram of mobile phone

Taking moment about P and equating to zero

$\therefore \quad M_P = 0 \Rightarrow (mg \times 0.06) - (m_1\, e\, \omega^2) \times 0.09 = 0$

$\Rightarrow (0.09 \times 9.81 \times 0.06) = (0.002 \times 0.00219 \times \omega^2) \times 0.09$

$\Rightarrow \quad \omega = 366.584 \text{ rad/s} = \dfrac{2\pi N}{60} \Rightarrow N = 3500.6 \text{ rpm}$

Hence, the correct option is (B).

Question Number: 29 **Question Type: MCQ**

A machine element is subjected to the following bi-axial state of stress: $\sigma_x = 80$ MPa; $\sigma_y = 20$ MPa; $\tau_{xy} = 40$ MPa. If the shear strength of the material is 100 MPa, the factor of safety as per Tresca's maximum shear stress theory is

(A) 1.0 (B) 2.0
(C) 2.5 (D) 3.3

Solution:

Given: $\sigma_x = 80$ MPa, $\sigma_y = 20$ MPa, $\tau_{xy} = 40$ MPa, $S_{ys} = 100$ MPa

Strength is tension, $S_{yt} = \dfrac{S_{ys}}{0.5} = \dfrac{100}{0.5}$

$\Rightarrow \quad S_{yt} = 200$ MPa

According to Tresca's maximum shear stress theory,

$$\left(\frac{\sigma_1 - \sigma_2}{2}\right) = \frac{S_{yt}}{2(FOS)}$$

σ_1 = Maximum principal stress and σ_2 = Minimum principal stress

$$\sigma_{1,2} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\Rightarrow \sigma_{1,2} = \left(\frac{80+20}{2}\right) \pm \sqrt{\left(\frac{80-20}{2}\right)^2 + 40^2}$$

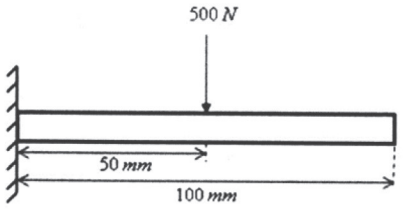
$\Rightarrow \quad \sigma_1 = 100$ MPa, $\sigma_2 = 0$

$$\therefore \left(\frac{100-0}{2}\right) = \frac{200}{2(FOS)} \Rightarrow \text{FOS} = 2$$

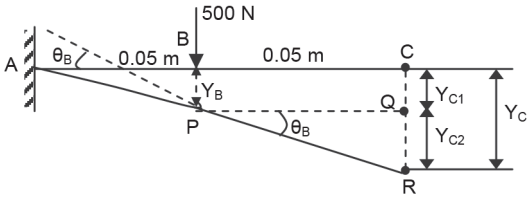
Hence, the correct option is (B).

Question Number: 30 **Question Type: NAT**

A cantilever beam with flexural rigidity of 200 N·m^2 is loaded as shown in the figure. The deflection (in mm) at the tip of the beam is _____.



Solution:



Deflection at C, $Y_C = Y_{C1} + Y_{C2}$ or $Y_C = Y_B + Y_{C2}$

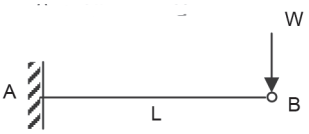
Now $\tan\theta_B = \dfrac{Y_{C2}}{0.050}$ {From $\triangle$PQR} or $Y_{C2} = 0.050 \tan\theta_B$

or $\quad Y_{C2} = 0.050\,(\theta_B)$

$\therefore \quad Y_C = Y_B + 0.050\,(\theta_B)$

where $\quad Y_B =$ Deflection at B

$\theta_B =$ Slope at B



$$Y_B = \frac{WL^3}{3EI} \text{ and } \theta_B = \frac{WL^2}{2EI}$$

$$\therefore Y_C = \frac{500\times0.05^3}{3EI} + 0.05\times\frac{500\times0.05^2}{2EI}$$

$$\Rightarrow Y_C = \frac{500\times0.05^3}{200}\left[\frac{1}{3}+\frac{1}{2}\right] = 2.6\times10^{-4}\text{ m}$$

or $$Y_C = 0.26 \text{ mm}$$

Hence, the correct answer is 0.24 to 0.28.

Question Number: 31 **Question Type: NAT**

A precision instrument package ($m = 1$ kg) needs to be mounted on a surface vibrating at 60 Hz. It is desired that only 5% of the base surface vibration amplitude be transmitted to the instrument. Assume that the isolation is designed with its natural frequency significantly lesser than 60 Hz, so that the effect of damping may be ignored. The stiffness (in N/m) of the required mounting pad is _____.

Solution:

Given: $f = 60$ Hz or $\omega = (2\pi \times 60)$ rad/sec

Transmissibility, $\in = 0.05$; mass, $m = 1$ kg

$\because$ No damping therefore $\xi = 0$

Now $$\in = \frac{1}{\pm\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]}$$

$$\Rightarrow 0.05 = \frac{1}{-\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]}$$

$$\Rightarrow -1 + \frac{(2\pi\times60)^2}{\omega_n^2} = \frac{1}{0.05}$$

$$\Rightarrow \omega_n^2 = \frac{(2\pi\times60)^2}{21} \Rightarrow \omega_n^2 = \frac{S}{m} = 6767.73$$

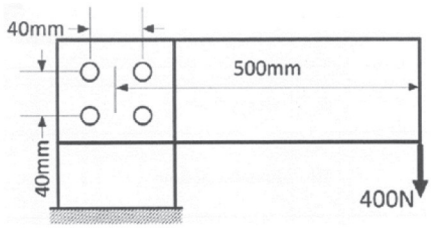
$\Rightarrow$ $$S = 6767.73 \times m$$

$\Rightarrow$ $$S = 6767.73 \text{ N/m}$$

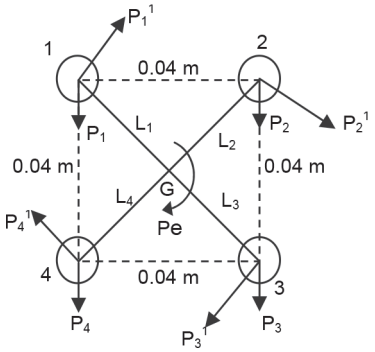
Hence, the correct answer is 6750 to 7150.

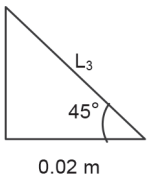
Question Number: 32 **Question Type: NAT**

A horizontal plate has been joined to a vertical post using four rivets arranged as shown in the figure. The magnitude of the load on the worst loaded rivet (in N) is _____.



Solution:





$$P = 400 \text{ N}, e = 0.5 \text{ m}$$

$$L = L_1 = L_2 = L_3 = L_4 = 0.02/\cos 45^o = 0.0283 \text{ m}$$

Primary shear force,

$$P_1 = P_2 = P_3 = P_4 = \frac{400}{4} = 100 \text{ N}$$

Secondary shear force,

$$P_1^1 = P_2^1 = P_3^1 = P_4^1 = \frac{PeL}{L_1^2 + L_2^2 + L_3^2 + L_4^2}$$

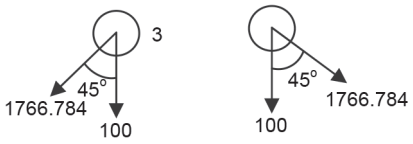
$$\Rightarrow P_1^1 = P_2^1 = P_3^1 = P_4^1 = \frac{400\times0.5\times0.0283}{4\times0.0283^2} = 1766.784\text{ N}$$

The worst loaded rivet is 2 or 3.

$\therefore$ Resultant force,

$$R = \sqrt{100^2 + 1766.784^2 + \left(2\times100\times1766.784\times\cos45^o\right)}$$

$$\Rightarrow \qquad R = 1838.85 \text{ N}$$



Hence, the correct answer is 1835 to 1845.

Question Number: 33 **Question Type: MCQ**

For flow through a pipe of radius R, the velocity and temperature distribution are as follows: $u(r, z) = C_1$, and $T(r, x) = C_2\left[1-\left(\frac{r}{R}\right)^3\right]$, where C_1 and C_2 are constants.

The bulk mean temperature is given by $T_m = \frac{2}{U_m R^2}\int_0^R u(r, x)T(r, x)\, rdr$, with U_m being the mean velocity of flow. The value of T_m is

(A) $\frac{0.5C_2}{U_m}$ (B) $0.5C_2$

(C) $0.6C_2$ (D) $\frac{0.6C_2}{U_m}$

Solution:

$$T_m = \frac{2}{U_m R^2}\int_0^R C_1 C_2\left[1-\left(\frac{r}{R}\right)^3\right]rdr$$

$$\Rightarrow T_m = \frac{2C_1 C_2}{U_m R^2}\int_0^R \left[r-\frac{r^4}{R^3}\right]dr$$

$$\Rightarrow T_m = \frac{2C_1 C_2}{U_m R^2}\left[\frac{r^2}{2}-\frac{r^5}{5R^3}\right]_0^R = \frac{2C_1 C_2}{U_m R^2}\left[\frac{R^2}{2}-\frac{R^2}{5}\right]$$

$$\Rightarrow T_m = \frac{0.6\, C_1 C_2}{U_m}$$

Since $u(r, x) = C_1$ which is constant, therefore $U_m = C_1$.

$$\Rightarrow \qquad T_m = 0.6C_2$$

Hence, the correct option is (C).

Question Number: 34 **Question Type: MCQ**

Match the following pairs:

	Equation		Physical interpretation
P	$\nabla \times \vec{V} = 0$	I	Incompressible continuity equation
Q	$\nabla \cdot \vec{V} = 0$	II	Steady flow
R	$\frac{D\vec{V}}{Dt} = 0$	III	Irrotational flow
S	$\frac{\partial \vec{V}}{\partial t} = 0$	IV	Zero acceleration of fluid particle

(A) P-IV, Q-I, R-II, S-III (B) P-IV, Q-III, R-I, S-II

(C) P-III, Q-I, R-IV, S-II (D) P-III, Q-I, R-II, S-IV

Solution: Incompressible continuity equation is given by

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0 \text{ or } \nabla \cdot \vec{V} = 0 \text{ where } V = f(u, v)$$

$$\text{Steady flow} \rightarrow \frac{\partial \vec{V}}{\partial t} = 0$$

Irrotational flow $\rightarrow$ Curl $\vec{V} = 0$ or $\nabla \times \vec{V} = 0$

$$\text{Zero acceleration of fluid} \rightarrow \frac{D\vec{V}}{Dt} = 0$$

Hence, the correct option is (C).

Question Number: 35 **Question Type: NAT**

The velocity field of an incompressible flow is given by $V = (a_1x + a_2y + a_3z)i + (b_1x + b_2y + b_3z)j + (c_1x + c_2y + c_3z)k$, where $a_1 = 2$ and $c_3 = -4$. The value of b_2 is _____.

Solution: $V = (a_1x + a_2y + a_3z)i + (b_1x + b_2y + b_3z)j + (c_1x + c_2y + c_3z)k$

For an incompressible flow to be possible, continuity equation is to be

$$\therefore \qquad \nabla \cdot \vec{V} = 0$$

or

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z} = 0$$

$$\frac{\partial u}{\partial x} = \frac{\partial}{\partial x}[a_1x + a_2y + a_3z] = a_1$$

$$\frac{\partial v}{\partial y} = \frac{\partial}{\partial y}[b_1x + b_2y + b_3z] = b_2 \text{ and}$$

$$\frac{\partial w}{\partial z} = \frac{\partial}{\partial z}[c_1x + c_2y + c_3z] = c_3$$

$$\therefore \qquad a_1 + b_2 + c_3 = 0 \Rightarrow 2 + b_2 - 4 = 0$$

$$\Rightarrow \qquad b_2 = 2$$

Hence, the correct answer is 1.9 to 2.1.

Question Number: 36 **Question Type: MCQ**

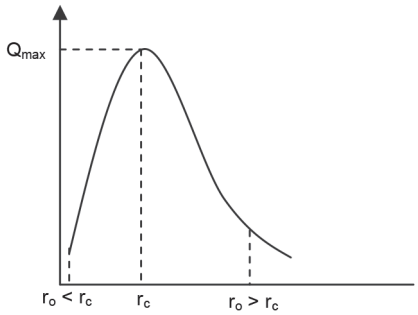
A 10 mm diameter electrical conductor is covered by an insulation of 2 mm thickness. The conductivity of the insulation is 0.08 W/m-K and the convection coefficient at the insulation surface is 10 W/m^2-K. Addition of further insulation of the same material will

(A) increase heat loss continuously
(B) decrease heat loss continuously
(C) increase heat loss to maximum and then decrease heat loss
(D) decrease heat loss to maximum and then increase heat loss

Solution: Critical radius, $r_c = \frac{k}{h} = \frac{0.08}{10} = 0.008$ m

$\Rightarrow$ $r_c = 8$ mm

Here, $r_c > r_o$ $[r_0 = 5$ mm$]$



$\therefore$ Addition of further insulation increases the critical radius and increases heat loss to a maximum and then decreases heat loss.

Hence, the correct option is (C).

Question Number: 37 **Question Type: NAT**

Temperature of nitrogen in a vessel of volume 2 m^3 is 288 K. A U-tube manometer connected to the vessel shows a reading of 70 cm of mercury (level higher in the end open to atmosphere). The universal gas constant is 8314 J/kmol-K, atmospheric pressure is 1.01325 bar, acceleration due to gravity is 9.81 m/s^2, and density of mercury is 13,600 kg/m^3. The mass of nitrogen (in kg) in the vessel is _____.

Solution:

Given: $V = 2$ m^3, $T = 288$ K

Gauge pressure, $P_g = 70$ cm of mercury or

$P_g = (13.6 \times 0.70 \times 9.81)$ kPa

$\Rightarrow$ $P_g = 93.3912$ kPa

Absolute pressure $P = (93.3912 + 101.325)$ kPa

$\Rightarrow$ $P = 194.71$ kPa

Characteristic gas constant, $R = \frac{R_o}{\text{Molecular weight}}$

$$\Rightarrow R = \frac{8.314}{28} \Rightarrow R = 0.29693 \text{ kJ/kg-K}$$

$$PV = mRT \Rightarrow (194.71 \times 2) = (m \times 0.29693 \times 288)$$

$\Rightarrow$ $m = 4.554$ kg

Hence, the correct answer is 4.4 to 4.6.

Question Number: 38 **Question Type: NAT**

Air ($\rho = 1.2$ kg/m^3 and kinematic viscosity, $\delta = 2 \times 10^{-5}$ m^2/s) with a velocity of 2 m/s flows over the top surface of a flat plate of length 2.5 m. If the average value of friction coefficient is $C_f = \frac{1.328}{\sqrt{\text{Re}_x}}$, the total drag force (in N) per unit width of the plate is _____.

Solution: Reynold number, $R_{ex} = \frac{\rho U_\infty x}{\mu} = \frac{U_\infty x}{\vartheta}$

$$\Rightarrow (R_{ex})_{x=2.5\text{m}} = \frac{2 \times 2.5}{2 \times 10^{-5}} = 2.5 \times 10^5$$

$$\therefore C_f = \frac{1.328}{\sqrt{2 \times 10^5}} \Rightarrow C_f = 2.656 \times 10^{-3}$$

$$C_f = \frac{F_D}{\frac{1}{2}\rho A U_\infty^2} \Rightarrow F_D = C_f \times \frac{1}{2} \times \rho \times L \times b \times U_\infty^2$$

$\Rightarrow$ $F_D = 2.656 \times 10^{-3} \times \frac{1}{2} \times 1.2 \times 2.5 \times 1 \times 2^2$

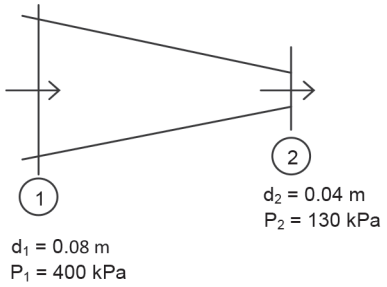
$\Rightarrow$ $F_D = 0.015936$ N

Hence, the correct answer is 0.0158 to 0.0162.

Question Number: 39 **Question Type: NAT**

Water ($\rho = 1000$ kg/m^3) flows through a venturimeter with inlet diameter 80 mm and throat diameter 40 mm. The inlet and throat guage pressures are measured to be 400 kPa and 130 kPa, respectively. Assuming the venturimeter to be horizontal and neglecting friction, the inlet velocity (in m/s) is _____.

Solution:



Continuity equation:

$$A_1 V_1 = A_2 V_2$$

$$\therefore \frac{\pi}{4} \times 0.08^2 \times V_1 = \frac{\pi}{4} \times 0.04^2 \times V_2$$

$$\Rightarrow \quad V_2 = 4V_1 \qquad (1)$$

Bernouli's equation:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\Rightarrow \left[\frac{P_1 - P_2}{\rho g}\right] \times 2g = V_2^2 - V_1^2$$

$$\therefore \left[\frac{400 - 130}{9.81}\right] \times 2 \times 9.81 = (4V_1)^2 - V_1^2$$

$$\Rightarrow \quad V_1 = 6 \text{ m/s}$$

Hence, the correct answer is 6.

Question Number: 40 **Question Type: NAT**

A well-insulated rigid container of volume 1 m^3 contains 1.0 kg of an ideal gas [C_p = 1000 J/(kg.K) and C_v = 800 J/(kg.K)] at a pressure of 10^5 Pa. A stirrer is rotated at constant rpm in the container for 1000 rotations and the applied torque is 100 N-m. The final temperature of the gas (in K) is _____.

Solution: $\delta Q = 0$ [Insulated]

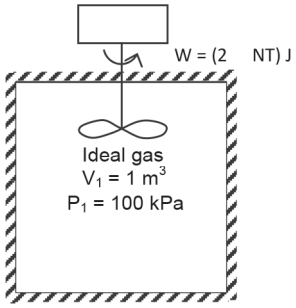
$$\delta W = -(2\pi \times 1000 \times 100) = 628.318 \text{ kJ}$$

1st law of thermodynamics

$$\delta Q = \delta W + \text{dU}$$

$$\Rightarrow \quad 0 = -628.318 + \text{dU}$$

$$\Rightarrow \quad \text{dU} = 628.318 \text{ kJ}$$



For ideal gas, $u = f(T)$

$$\therefore \quad mC_v(T_2 - T) = 628.318$$

$$P_1 V_1 = mRT_1 \Rightarrow T_1 = \frac{P_1 V_1}{mR} \Rightarrow T_1 = \frac{100 \times 1}{1 \times (C_P - C_V)}$$

$$\Rightarrow T_1 = \frac{100}{0.2} = 500 \text{ K}$$

$$\therefore \quad 1 \times 0.8 \times (T_2 - 500) = 628.318$$

$$\Rightarrow \quad T_2 = 1285.4 \text{ K}$$

Hence, the correct answer is 1283.4 to 1287.4.

Question Number: 41 **Question Type: NAT**

Steam enters a well insulated turbine and expands isentropically throughout. At an intermediate pressure, 20 percent of the mass is extracted for process heating and the remaining steam expands isentropically to 9 kPa.

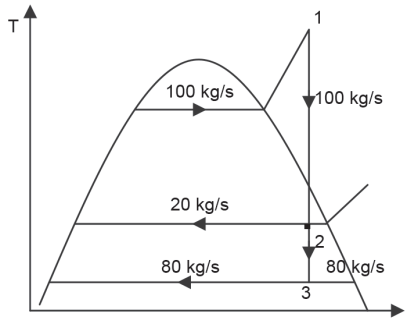
Inlet to turbine: P = 14 MPa, T = 560°C, h = 3486 kJ/kg, s = 6.6 kJ/(kg.K)

Intermediate stage: h = 2776 kJ/kg

Exit of turbine: P = 9 kPa, h_f = 174 kJ/kg, h_g = 2574 kJ/kg, s_f = 0.6 kJ/(kg.K), s_g = 8.1 kJ/(kg·K)

If the flow rate of steam entering the turbine is 100 kg/s, then the work output (in MW) is _____.

Solution:



Work output, $W = \dot{m}_1 (h_1 - h_2) + \dot{m}_2 (h_2 - h_3)$

$$\Rightarrow W = 100(3486 - 2776) + 80(2776 - h_3)$$

Now $S_1 = S_2 = S_3 = 6.6 = [S_f + x_3 S_{fg}]_{9 \text{ kPa}}$

$$\Rightarrow \quad 6.6 = 0.6 + x_3(8.1 - 0.6)$$

$$\Rightarrow \quad x_3 = 0.8$$

$$\therefore \quad h_3 = [h_f + x_3 h_{fg}]_{9 \text{ kpa}} = 174 + 0.8(2574 - 174)$$

$$\Rightarrow \quad h_3 = 2094 \text{ kJ/kg}$$

$$\therefore \quad W = 100(3486 - 2776) + 80(2776 - 2094)$$

$$\Rightarrow \quad W = 125560 \text{ kW} \Rightarrow W = 125.56 \text{ MW}$$

Hence, the correct answer is 123.56 to 127.56.

Question Number: 42 **Question Type: MCQ**

If any two columns of a determinant $P = \begin{vmatrix} 4 & 7 & 8 \\ 3 & 1 & 5 \\ 9 & 6 & 2 \end{vmatrix}$ are interchanged, which one of the following statements regarding the value of the determinant is CORRECT?

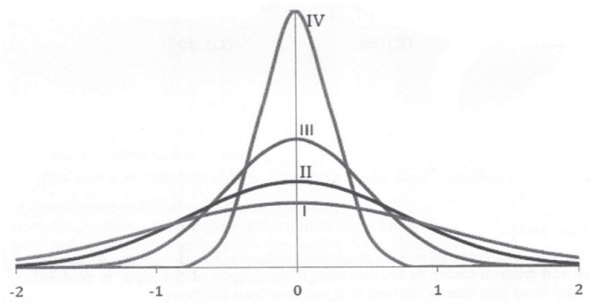
(A) Absolute value remains unchanged but sign will change.
(B) Both absolute value and sign will change.
(C) Absolute value will change but sign will not change.
(D) Both absolute value and sign will remain unchanged.

Solution: If any two columns of a determinant $P = \begin{vmatrix} 4 & 7 & 8 \\ 3 & 1 & 5 \\ 9 & 6 & 2 \end{vmatrix}$ are interchanged, then absolute value remains the same but sign will change.

Hence, the correct option is (A).

Question Number: 43 **Question Type: MCQ**

Among the four normal distributions with probability density functions as shown below, which one has the lowest variance?



(A) I (B) II
(C) III (D) IV

Solution: As the total area above x-axis under any normal curve is equal to 1, a normal curve with highest peak will have less variance

$\therefore$ The normal curve IV has the lowest variance.

Hence, the correct option is (D).

Question Number: 44 **Question Type: NAT**

Simpson's $\frac{1}{3}$-rule is used to integrate the function $f(x) = \frac{3}{5}x^2 + \frac{9}{5}$ between $x = 0$ and $x = 1$ using the least number of equal sub-intervals. The value of the integral is _____.

Solution: Given function is $f(x) = \frac{3}{5}x^2 + \frac{9}{5}$

The number of intervals in Simpson's $\frac{1}{3}$-rule has to be even.

The least number of intervals $= n = 2$

Here $a = 0$ and $b = 1$

$$\Rightarrow \quad h = \frac{b-a}{n} = \frac{1-0}{2} = \frac{1}{2}$$

$X = x_i$	0	$\frac{1}{2}$	1
$Y_i = f(x_i)$	$\frac{9}{5}$	$\frac{39}{20}$	$\frac{12}{5}$

By Simpson's $\frac{1}{3}$-rule, we have

$$\int_0^1 f(x)dx = \int_0^1 \left(\frac{3}{5}x^2 + \frac{9}{5}\right)dx = \frac{h}{3}\left[(y_0 + y_2) + 4y_1\right]$$

$$= \frac{\left(\frac{1}{2}\right)}{3}\left[\left(\frac{9}{5} + \frac{12}{5}\right) + 4 \times \frac{39}{20}\right]$$

$$= \frac{1}{6}\left[\frac{21}{5} + \frac{39}{5}\right] = 2$$

Hence, the correct answer is 2.

Question Number: 45 **Question Type: MCQ**

The value of $\lim_{x \to 0} \frac{1 - \cos\left(x^2\right)}{2x^4}$ is

(A) 0 (B) $\frac{1}{2}$
(C) $\frac{1}{4}$ (D) undefined

Solution:

We have $\lim_{x \to 0} \frac{1 - \cos\left(x^2\right)}{2x^4} = \lim_{x \to 0} \frac{2\sin^2\left(\frac{x^2}{2}\right)}{2x^4}$

$$= \lim_{x \to 0} \frac{\sin^2\left(\frac{x^2}{2}\right)}{2^2\left(\frac{x^2}{2}\right)^2}$$

$$= \lim_{x \to 0} \frac{1}{4}\left(\frac{\sin\left(\frac{x^2}{2}\right)}{\left(\frac{x^2}{2}\right)}\right)^2$$

$$= \frac{1}{4}\left[\lim_{x \to 0} \frac{\sin\left(\frac{x^2}{2}\right)}{\left(\frac{x^2}{2}\right)}\right]^2$$

$$= \frac{1}{4}\left[\lim_{\frac{x^2}{2}\to 0}\frac{\sin\left(\frac{x^2}{2}\right)}{\left(\frac{x^2}{2}\right)}\right]^2$$

$$= \frac{1}{4} \times 1 \left(\because \lim_{\theta\to 0}\frac{\sin\theta}{\theta} = 1\right) = \frac{1}{4}.$$

Hence, the correct option is (C).

Question Number: 46 **Question Type: MCQ**

Given two complex numbers $z_1 = 5 + \left(5\sqrt{3}\right)i$ and $z_2 = \frac{2}{\sqrt{3}} + 2i$, the argument of $\frac{z_1}{z_2}$ in degrees is

(A) 0 (B) 30
(C) 60 (D) 90

Solution: Given $Z_1 = 5 + \left(5\sqrt{3}\right)i$ and $Z_2 = \frac{2}{\sqrt{3}} + 2i$

We know that the argument of $\frac{Z_1}{Z_2}$

$$= \arg\left(\frac{Z_1}{Z_2}\right) = \arg(Z_1) - \arg(Z_2) \qquad (1)$$

$$\arg(Z_1) = \arg\left(5 + \left(5\sqrt{3}\right)i\right) = \tan^{-1}\left(\frac{5\sqrt{3}}{5}\right)$$

$$= \tan^{-1}\left(\sqrt{3}\right) = 60°$$

and $$\arg(Z_2) = \arg\left(\frac{2}{\sqrt{3}} + 2i\right) = \tan^{-1}\left(\frac{\frac{2}{1}}{\left(\frac{2}{\sqrt{3}}\right)}\right)$$

$$= \tan^{-1}\left(\sqrt{3}\right) = 60°$$

From Eq. (1), $\arg\left(\frac{Z_1}{Z_2}\right) = 60° - 60° = 0.$

Hence, the correct option is (A).

Question Number: 47 **Question Type: MCQ**

Consider fully developed flow in a circular pipe with negligible entrance length effects. Assuming the mass flow rate, density and friction factor to be constant, if the length of the pipe is doubled and the diameter is halved, the head loss due to friction will increase by a factor of

(A) 4 (B) 16
(C) 32 (D) 64

Solution: Head loss due to friction, $h_f = \frac{f L V^2}{2gD}$

$\dot{m}$, ρ, f are constant

Now $\dot{m} = \rho A V \Rightarrow V = \frac{\dot{m}}{\rho A} = \frac{\dot{m}\times 4}{\rho \pi D^2}$

$$\therefore h_f = \frac{fL}{2gD} \times \left(\frac{\dot{m}\times 4}{\rho \pi D^2}\right)^2$$

$$\Rightarrow h_f = \frac{16\ f L \dot{m}^2}{2g\rho^2\pi^2 D^5}$$

In the above equation, all terms are constant except D and L.

$$\Rightarrow \qquad h_f \propto \frac{L}{D^5}$$

When D is halved and L is doubled, then

$$\Rightarrow \qquad h_f \propto \frac{(2L)}{\left(\frac{D}{2}\right)^5} = \frac{64L}{D^5}$$

$\therefore$ Head loss will increase by a factor of 64.

Hence, the correct option is (D).

Question Number: 48 **Question Type: MCQ**

The Blausius equation related to boundary layer theory is a

(A) third-order linear partial differential equation
(B) third-order nonlinear partial differential equation
(C) second-order nonlinear ordinary differential equation
(D) third-order nonlinear ordinary differential equation

Solution:

Blausius equation

$$\frac{\partial \psi}{\partial y}\frac{\partial^2 \psi}{\partial x \partial y} - \frac{\partial \psi}{\partial x}\frac{\partial^2 \psi}{\partial y^2} = \nu \frac{\partial^3 \psi}{\partial y^3}$$

where $U_x = \frac{\partial \psi}{\partial y}$ and $U_y = -\frac{\partial \psi}{\partial x}$

The above equation is third-order nonlinear ordinary differential equation.

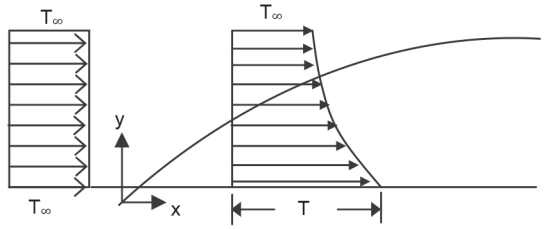
Hence, the correct option is (D).

Question Number: 49 **Question Type: MCQ**

For flow of viscous fluid over a flat plate, if the fluid temperature is the same as the plate temperature, the thermal boundary layer is

(A) thinner than the velocity boundary layer
(B) thicker than the velocity boundary layer
(C) of the same thickness as the velocity boundary layer
(D) not formed at all

Solution:



If the fluid temperature is the same as the plate temperature, then $T_S = T_\infty$ and hence no temperature gradient will occur. Therefore, thermal boundary layer will not be formed at all.

Hence, the correct option is (D).

Question Number: 50 **Question Type: MCQ**

For an ideal gas with constant values of specific heats, for calculation of the specific enthalpy,

(A) it is sufficient to know only the temperature
(B) both temperature and pressure are required to be known
(C) both temperature and volume are required to be known
(D) both temperature and mass are required to be known

Solution: For ideal gas, enthalpy is the function of temperature.

$$h = f(T)$$

Hence for calculation of specific enthalpy, it is sufficient to know only the temperature.

Hence, the correct option is (A).

Question Number: 51 **Question Type: NAT**

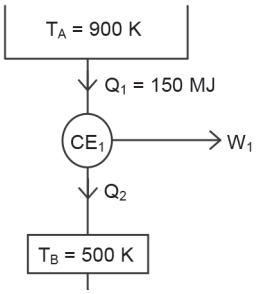
A Carnot engine (CE-1) works between two temperature reservoirs A and B, where $T_A = 900$ K and $T_B = 500$ K. A second Carnot engine (CE-2) works between temperature reservoirs B and C, where $T_C = 300$ K. In each cycle CE-1 and CE-2, all the heat rejected by CE-1 to reservoir B is used by CE-2. For one cycle of operation, if the net Q absorbed by CE-1 from reservoir A is 150 MJ, the net heat rejected to reservoir C by CE-2 (in MJ) is _____.

Solution:

For CE_1

$$\frac{Q_1}{T_A} = \frac{Q_2}{T_B}$$

$$\therefore Q_2 = \frac{150 \times 500}{900} = 83.34\,\text{MJ}$$



For CE_2

$$\frac{Q_2}{T_B} = \frac{Q_3}{T_C}$$

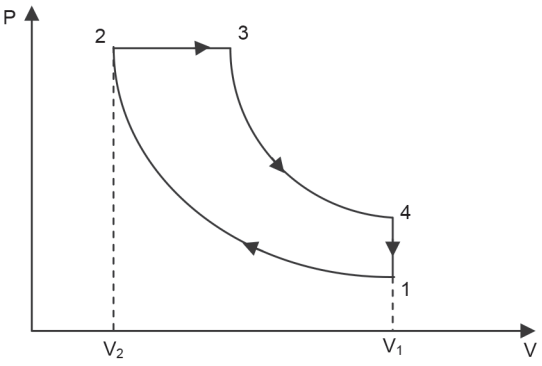
$$\therefore Q_3 = \frac{83.34 \times 300}{500} = 50\,\text{MJ}$$

Hence, the correct answer is 50.

Question Number: 52 **Question Type: NAT**

Air enters a diesel engine with a density of 1.0 kg/m^3. The compression ratio is 21. At steady state, the air intake is 30×10^{-3} kg/s and the network output is 15 kW. The mean effective pressure (in kPa) is _____.

Solution:



Given: $\rho_{air} = 1.0$ kg/m^3

$$r = \frac{V_1}{V_2} = 21 \Rightarrow V_2 = \frac{V_1}{21}$$

$$\dot{m}_{air} = 30 \times 10^{-3}\ \text{kg/s}$$

$$W_{net} = 15\ \text{kW}$$

Now $$V_1 = \frac{\dot{m}_{air}}{\rho_{air}} = \frac{30 \times 10^{-3}}{1.0} = 0.03\,\text{m}^3/\text{s}$$

Mean effective pressure, $p_m = \dfrac{W_{net}}{\text{Swept volume}}$

or $$p_m = \frac{W_{net}}{(V_1 - V_2)} = \frac{W_{net}}{V_1 - \frac{V_1}{21}}$$

$$\Rightarrow p_m = \frac{21 \times W_{net}}{20 V_1} = \frac{21 \times 15}{20 \times 0.03}$$

$$\Rightarrow \quad p_m = 525 \text{ kPa}$$

Hence, the correct answer is 525.

Question Number: 53 **Question Type: NAT**

A stream of moist air (mass flow rate = 10.1 kg/s) with humidity ratio of $0.01 \frac{\text{kg}}{\text{kg dry air}}$ mixes with a second stream of superheated water vapor flowing at 0.1 kg/s. Assuming proper and uniform mixing with no condensation, the humidity ratio of the final stream $\left(\text{in} \frac{\text{kg}}{\text{kg dry air}}\right)$ is _____.

Solution: $m_1\ \omega_1 + m_2\ \omega_2 = m_3\ \omega_3$

$\Rightarrow \quad (10.1 \times 0.01) + (0.1 \times 1) = (10.1 + 0.1) \times \omega_3$

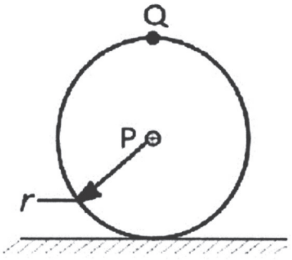
$\Rightarrow \quad \omega_3 = 0.0197$ kg/kg dry air

or $\quad \omega_3 \sim 0.02$ kg/kg dry air

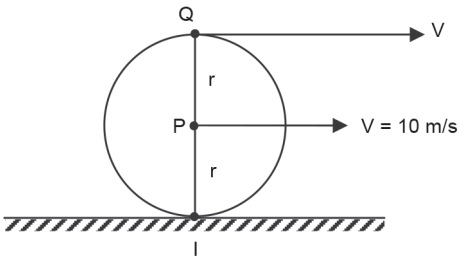
Hence, the correct answer is 0.02.

Question Number: 54 **Question Type: NAT**

A wheel of radius r rolls without slipping on a horizontal surface shown below. If the velocity of point P is 10 m/s in the horizontal direction, the magnitude of velocity of point Q (in m/s) is _____.



Solution:



I is the instantaneous center and about I, the wheel is rolling without slipping.

$$V_P = \omega r \Rightarrow 10 = \omega r \Rightarrow \omega = \frac{10}{r}$$

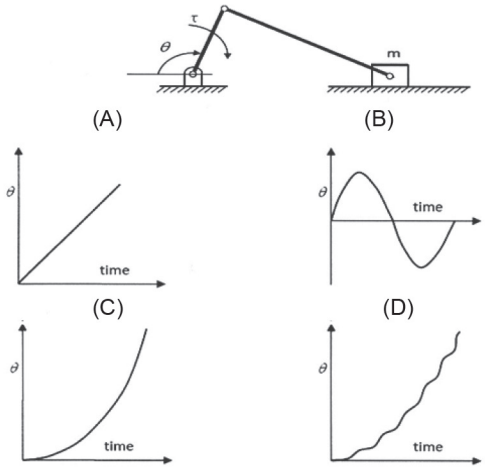
$$\text{Velocity of } Q,\ V_Q = \omega (2r) = \frac{10}{r} \times 2r$$

$$\Rightarrow \quad V_Q = 20 \text{ m/s}$$

Hence, the correct answer is 20.

Question Number: 55 **Question Type: MCQ**

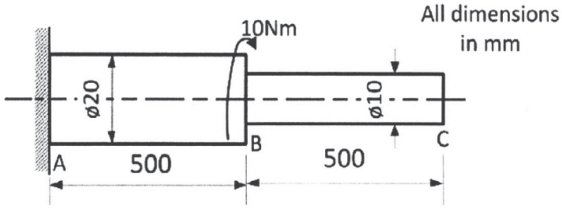
Consider a slider crank mechanism with non-zero masses and inertia. A constant torque τ is applied on the crank as shown in the figure. Which of the following plots best resembles variation of crank angle, θ versus time?



Solution: Hence, the correct option is (D).

Question Number: 56 **Question Type: NAT**

Consider a stepped shaft subjected to a twisting moment applied at B as shown in the figure. Assume shear modulus, $G = 77$ GPa. The angle of twist at C (in degrees) is _____.



Solution: Angle of twist at B = Angle of twist at C

$$(\theta)_B = \frac{TL}{GJ} = \frac{10 \times 0.5}{77 \times 10^9 \times \frac{\pi}{32} \times 0.02^4}$$

$$\Rightarrow \quad \theta_B = 4.1339 \times 10^{-3} \text{ radians}$$

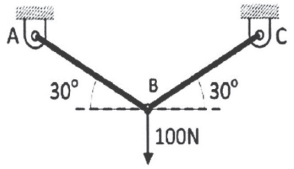
$$\Rightarrow \qquad \theta_B = 4.1339 \times 10^{-3} \times \frac{180}{\pi} \text{ degrees}$$

or $$\theta_B = \theta_C = 0.2368 \text{ degrees.}$$

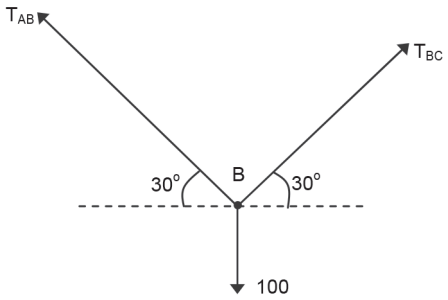
Hence, the correct answer is 0.22 to 0.25.

Question Number: 57 **Question Type: NAT**

Two identical trusses support a load of 100 N as shown in the figure. The length of each truss is 1.0 m; cross-sectional area is 200 mm^2, Young's modulus $E = 200$ GPa. The force in the truss AB (in N) is _____.



Solution:



$$\Sigma F_x = 0 \Rightarrow T_{AB} \cos 30^\circ = T_{BC} \cos 30^\circ$$

$$\Rightarrow \qquad T_{AB} = T_{BC}$$

$$\Sigma F_y = 0 \Rightarrow T_{AB} \cos 30^\circ + T_{BC} \cos 30^\circ = 100 \text{ N}$$

$$\Rightarrow \qquad T_{AB} \cos 30^\circ + T_{AB} \cos 30^\circ = 100 \text{ N}$$

$$\Rightarrow \qquad 2\, T_{AB} \cos 30^\circ = 100 \text{ N}$$

$$\Rightarrow \qquad T_{AB} = 100 \text{ N}$$

Hence, the correct answer is 100.

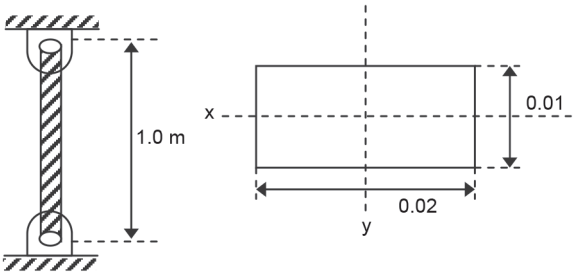
Question Number: 58 **Question Type: NAT**

Consider a steel (Young's modulus $E = 200$ GPa) column hinged on both sides. Its height is 1.0 m and cross-section is 10 mm × 20 mm. The lowest Euler critical buckling load (in N) is _____.

Solution: Lowers Euler critical buckling load, P_{cr}

$$P_{cr} = \frac{\pi^2 E I_{min}}{L^2}$$

$$I_{XX} = \frac{0.02 \times 0.01^3}{12} \text{ and } I_{YY} = \frac{0.01 \times 0.02^3}{12}$$



$$I_{min} = I_{XX} = \frac{0.02 \times 0.01^3}{12} = 2 \times 10^{-8} \text{ m}^4$$

$$\therefore \; P_{cr} = \frac{\pi^2 \times 200 \times 10^9 \times 2 \times 10^{-8}}{12} = 3289.87 \text{ N}$$

Hence, the correct answer is 3285 to 3295.

Question Number: 59 **Question Type: NAT**

A swimmer can swim 10 km in 2 hours when swimming along the flow of a river. While swimming against the flow, she takes 5 hours for the same distance. Her speed in still water (in km/h) is _____.

Solution: When swimming along the flow of water (V_f) the relative velocity of the swimmer is

$$= V + V_f \text{ km/hr}$$

V = Velocity of swimmer

When swimming against the flow, velocity

$$= V - V_f \text{ km/hr}$$

$\therefore$ Time taken while swimming along the flow

$$2 = \frac{10}{V + V_f}$$

$$\Rightarrow \qquad V + V_f = 5 \qquad (1)$$

Time taken while swimming against the flow

$$5 = \frac{10}{V - V_f} \Rightarrow V - V_f = 2 \qquad (2)$$

From Eqs. (1) and (2)

$$V = 3.5 \text{ m/s.}$$

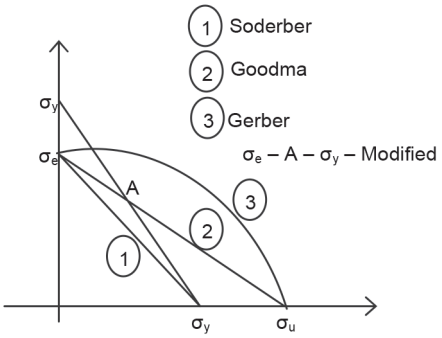
Hence, the correct answer is 3.5.

Question Number: 60 **Question Type: MCQ**

Which one of the following is the most conservative fatigue failure criterion?

(A) Soderberg (B) Modified Goodman
(C) ASME Elliptic (D) Gerber

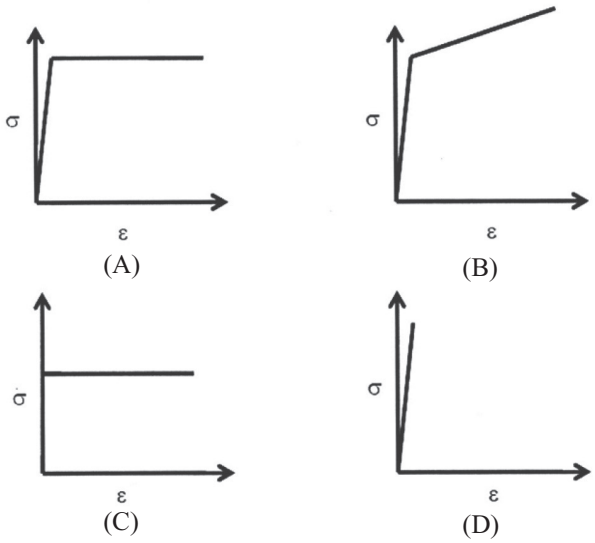
Solution: The most conservative criterion is Soderberg criterion.



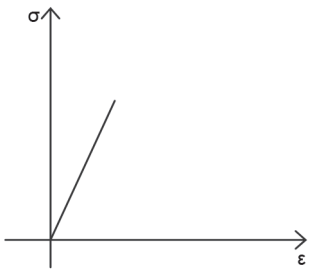
Hence, the correct option is (A).

Question Number: 61 **Question Type: MCQ**

Which one of the following types of stress–strain relationship best described the behavior of brittle materials, such as ceramics and thermosetting plastics (σ = stress and ε = strain)?



Solution: For Brittle materials, there will not be any indication of yielding and the failure is catastrophic which is represented by:



Hence, the correct option is (D).

Question Number: 62 **Question Type: MCQ**

Match the following products with preferred manufacturing processes:

	Product		Process
P	Rails	1	Blow molding
Q	Engine crankshaft	2	Extrusion
R	Aluminum channels	3	Forging
S	PET water bottles	4	Rolling

(A) P-4, Q-3, R-1, S-2 (B) P-4, Q-3, R-2, S-1
(C) P-2, Q-4, R-3, S-1 (D) P-3, Q-4, R-2, S-1

Solution: Rails are manufactured using rolling because of large lengths. Engine crankshaft can be made by forging. Aluminum channels are made using extrusion. Water bottles are made by blow mounding operation.

Hence, the correct option is (B).

Question Number: 63 **Question Type: MCQ**

Holes of diameter $25.0^{+0.040}_{+0.020}$ mm are assembled interchangeably with the pins of diameter $25.0^{+0.005}_{-0.008}$ mm. The minimum clearance in the assembly will be

(A) 0.048 mm (B) 0.015 mm
(C) 0.005 mm (D) 0.008 mm

Solution:

	Hole	Shaft
min	25.02	24.992
max	25.04	25.005

As the maximum shaft diameter is less than minimum hole diameter, the fit is a clearance fit.

$$\text{Minimum clearance} = (\text{Hole})_{\min} - (\text{Shaft})_{\max}$$
$$= 25.02 - 25.005$$
$$\text{Maximum} = 0.015 \text{ mm}$$

Hence, the correct option is (B).

Question Number: 64 **Question Type: NAT**

Under certain cutting conditions, doubling the cutting speed reduces the tool life to $\left(\frac{1}{16}\right)^{\text{th}}$ of the original. Taylor's tool life index (n) for this tool-work piece combination will be _____.

Solution: Let $V_1 = V$ and $T_1 = T$

$$V_2 = 2V \quad T_2 = \frac{T}{16}$$

By Taylor's tool life equation

$$VT^n = C \Rightarrow V_1 T_1^n = V_2 T_2^n$$

$$V \cdot T^n = 2V\left(\frac{T}{16}\right)^n \Rightarrow 16^n = 2 \Rightarrow 2^{4n} = 2$$

$\therefore 4n = 1 \Rightarrow n = \frac{1}{4} = 0.25$

Hence, the correct answer is 0.25.

Question Number: 65 **Question Type: MCQ**

In a linear arc welding process, the heat input per unit length is inversely proportional to

(A) welding current
(B) welding voltage
(C) welding speed
(D) duty cycle of the power source

Solution: Heat input $Q = CVI$

$C =$ fraction of time during which arc is on $= \frac{L}{v}$

$L =$ Length of weld, $v =$ welding speed

$\therefore \frac{Q}{L} = \frac{VI}{v} \Rightarrow Q \propto \frac{1}{v}$

Hence, the correct option is (C).

GATE 2015 Solved Paper
ME: Mechanical Engineering
Set – 3

Number of Questions: 65 **Total Marks:100.0**

Wrong answer for MCQ will result in negative marks, (−1/3) for 1 Mark Questions and (−2/3) for 2 Marks Questions.

General Aptitude

Number of Questions: 10 **Section Marks: 15.0**

Q.1 to Q.5 carry 1 mark each and Q.6 to Q.10 carry 2 marks each.

Question Number: 1 **Question Type: MCQ**

Ram and Shyam shared a secret and promised to each other that it would remain between them. Ram expressed himself in one of the following ways as given in the choices below. Identify the correct way as per standard English.

(A) It would remain between you and me.
(B) It would remain between I and you.
(C) It would remain between you and I.
(D) It would remain with me.

Solution: Choice (A) is correct as this is an objective case. The first person objective is 'me' and not 'I.'. The first person is always placed at the end and hence choice (A) is correct.

Hence, the correct option is (A).

Question Number: 2 **Question Type: MCQ**

In the following question, the first and the last sentence of the passage are in order and numbered 1 and 6. The rest of the passage is split into 4 parts and numbered as 2, 3, 4 and 5. These 4 parts are not arranged in proper order. Read the sentences and arrange them in a logical sequence to make a passage and choose the correct sequence from the given options.

1. On Diwali, the family rises early in the morning.
2. The whole family, including the young and the old enjoy doing this.
3. Children let off fireworks later in the night with their friends.
4. At sunset, the lamps are lit and the family performs various rituals.
5. Father, mother, and children visit relatives and exchange gifts and sweets.
6. Houses look so pretty with lighted lamps all around.

(A) 2, 5, 3, 4 (B) 5, 2, 4, 3
(C) 3, 5, 4, 2 (D) 4, 5, 2, 3

Solution: The next sentence after (1) is (5) as it explains what people (or the family members) do after waking up. Sentence (2) continues explaining sentence (5). The 'this' in (2) is what is mentioned in (5). Once the morning's description is over, the sunset's (or evening's) activities are given. Hence (4) follows next. Night follows in the end and so does the second last sentence. This makes 152436 the correct sequence.

Hence, the correct option is (B).

Question Number: 3 **Question Type: NAT**

From a circular sheet of paper of radius 30 cm, a sector of 10% area is removed. If the remaining part is used to make a conical surface, then the ratio of the radius and height of the cone is _____.

Solution: Area of the sector is 10% of the area of the circular sheet.

$\therefore$ The central angle of the sector is 10% of 360° i.e. 36°.

The remaining part is a sector whose central angle is 324°.

The remaining part is used to make a conical surface.

$\therefore$ Arc length of the remaining part is the circumference of the base of the cone.

Also the radius of the sector is the slant height of the cone.

Let the radius of the cone be r.

$$\frac{324}{360}(2\pi\,(30)) = 2\pi r \Rightarrow r = 27.$$

Slant height of the cone $= 30$

$$\text{Height of the cone } (h) = \sqrt{30^2 - 27^2} = 3\sqrt{19}$$

$$r : h = \frac{27}{3\sqrt{19}} = \frac{9}{\sqrt{19}}$$

Hence, the correct answer is $9 : \sqrt{19}$.

Question Number: 4 **Question Type: MCQ**

log tan 1° + log tan 2° + … + log tan 89° is _____

(A) 1 (B) $1/\sqrt{2}$

(C) 0 (D) -1

Solution: $\log \tan 1° + \log \tan 2° + \ldots + \log \tan 89°$

$= \log (\tan 1°)(\tan 2°) \ldots (\tan 89°)$

$= \log (\tan 1°)(\tan 2°) \ldots (\tan 45°) \ldots (\tan 89°)$

$= \log 1$ ($\because \tan\theta \times \tan(90 - \theta) = 1$ and $\tan 45° = 1$) $= 0$

Hence, the correct option is (C).

Question Number: 5 **Question Type: MCQ**

Ms. *X* will be in Bagdogra from 01/05/2014 to 20/05/2014 and from 22/05/2014 to 31/05/2014. On the morning of 21/05/2014, she will reach Kochi via Mumbai.

Which one of the statements below is logically valid and can be inferred from the above sentences?

(A) Ms. *X* will be in Kochi for one day, only in May.
(B) Ms. *X* will be in Kochi for only one day in May.
(C) Ms. *X* will be only in Kochi for one day in May.
(D) Only Ms. *X* will be Kochi for one day in May.

Solution: We are given that Mr. *X* will be in Bagdogra from 01/0512014 to 20/05/2014 and 22/05/2014 to 3/05/2014 and he will reach Kochi on 2/05/2014. But again on 22/05/2014 Mr. *X* will be in Bagdogra. This means that Mr. *X* will be in Kochi for only one day in May.

Hence, the correct option is (B).

Question Number: 6 **Question Type: MCQ**

Choose the most appropriate word from the options given below to complete the following sentence.

If the athlete had wanted to come first in the race, he _____ several hours every day.

(A) should practice (B) should have practiced
(C) practiced (D) should be practiced

Solution: The sentence uses the past perfect tense to explain a situation which could have been changed for a suitable outcome. The past perfect should be followed by a 'have' as it shows the 'if …….then' clause. This makes choice (B) the correct answer.

Hence, the correct option is (B).

Question Number: 7 **Question Type: MCQ**

Choose the most suitable one word substitute for the following expression:

Connotation of a road way

(A) Pertinacious (B) Viaticum
(C) Clandestine (D) Ravenous

Solution: 'Viaticum' is an allowance for traveling expenses. This is the only word that relates to road or way. 'Pertinacious' means a 'persevering' or a 'patient' person. 'Ravenous' means very hungry. 'Clandestine' means done in a secret place or privately. None of the choices, except (B), relate to a road or way.

Hence, the correct option is (B).

Question Number: 8 **Question Type: MCQ**

Choose the correct verb to fill in the blank below:

Let us _____.

(A) introvert (B) alternate
(C) atheist (D) altruist

Solution: 'Alternate' means to occur by turns. The sentence requires a verb. Among the choices, only choice (B) suits the sentence as it indicates that people wanted to take turns (to do something). 'Introvert' is one who does not gel with people well and keeps to himself or herself. 'Atheist' is a person who does not believe in the existence of God. 'Altruist' is a person who is selfless. This makes only choice (B) suitable to the context.

Hence, the correct option is (B).

Question Number: 9 **Question Type: MCQ**

Find the missing sequence in the letter series below:

A, CD, GHI, ?, UVWXY

(A) LMN (B) MNO
(C) MNOP (D) NOPQ

Solution: A, CD, GHI?, UVWXY

This question is based on Letter/Alphabet series. And we are asked to find the missing element.

A (B) C D (E F) G H I (J K L) M N O P

When we compare the given questions with the series above, we can see that B, E, F, have been omitted. So alternately omitting the number of alphabets in increasing order stating from 1 is the logic. And also the number of alphabets in each element are also gradually increasing. So, the missing element has to be M N O P.

Hence, the correct option is (C).

Question Number: 10 **Question Type: MCQ**

If $x > y > 1$, which of the following must be true?

i. $\ln x > \ln y$ ii. $e^x > e^y$
iii. $y^x > x^y$ iv. $\cos x > \cos y$
(A) (i) and (ii) (B) (i) and (iii)
(C) (iii) and (iv) (D) (ii) and (iv)

Solution: $x > y > 1$ (1)

(i) For any number p greater than 1, $\ln p$ increases with p ($p > 0$)

$\therefore$ (1) implies $\ln x > \ln y$

(ii) For any positive number p, e^p increases with p

$\therefore \quad e^x > e^y$

(iii) If $x = 3, y = 2, x^y > y^X$

If $x = 4, y = 3, x^y < y^x$. Hence (iii) is not true.

(iv) For $\pi/2 > x > y > 1$

$\cos x < \cos y$

Hence (iv) is not true.

Only (i) and (ii) must be true.

Hence, the correct option is (A).

Mechanical Engineering

Number of Questions: 55 **Section marks: 85.0**

Q.11 to Q.35 carry 1 mark each and Q.36 to Q.65 carry 2 marks each.

Question Number: 11 **Question Type: MCQ**

Sales data of a product is given in the following table:

Month	January	February	March	April	May
Number of units sold	10	11	16	19	25

Regarding forecast for the month of June, which one of the following statements is TRUE?

(A) Moving average will forecast a higher value compared to regression.
(B) Higher the value of order N, the greater will be the forecast value by moving average.
(C) Exponential smoothing will forecast a higher value compared to regression.
(D) Regression will forecast a higher value compared to moving average.

Solution: As the trend is increasing, regression will forecast a higher value than the moving average.

Hence, the correct option is (D).

Question Number: 12 **Question Type: MCQ**

The chance of a student passing an exam is 20%. The chance of a student passing the exam and getting above 90% marks in it is 5%. GIVEN that a student passes the examination, the probability that the student gets above 90% marks is

(A) $\frac{1}{18}$ (B) $\frac{1}{4}$

(C) $\frac{2}{9}$ (D) $\frac{5}{18}$

Solution: Let A and B denote the events of a student passing an exam and a student getting above 90% marks in the exam respectively

$$\therefore \quad P(A) = \frac{20}{100} = 0.2, P(A \cap B) = \frac{5}{100} = 0.05$$

Given that a student passes the examination, the probability that the student gets above 90% marks

$$= P\left(\frac{B}{A}\right) = \frac{P(A \cap B)}{P(A)} = \frac{0.05}{0.2} = \frac{1}{4}.$$

Hence, the correct option is (B).

Question Number: 13 **Question Type: NAT**

The surface integral $\iint_S \frac{1}{\pi}\left(9x\bar{i} - 3y\bar{j}\right)\cdot n\,dS$ over the sphere given by $x^2 + y^2 + z^2 = 9$ is _____.

Solution: Let $\overline{F} = \frac{1}{\pi}\left(9x\bar{i} - 3y\bar{j}\right)$

$$\Rightarrow \quad \text{div}\left(\sqrt{1+\frac{4}{\pi^2}}\right)t\Big]_0^{\frac{\pi}{2}} = [9] - \frac{1}{\pi}[3] = \frac{6}{\pi}$$

Now $\iint_S \frac{1}{\pi}\left(9x\bar{i} - 3y\bar{j}\right)\cdot\bar{n}\,ds = \iint_S \overline{F}\cdot\bar{n}\,ds$

$$= \iiint_V \text{Div}\,\overline{F}\,dv$$

$$= \iiint_V \left(\frac{6}{\pi}\right)dv = \frac{6}{\pi}\iiint_V dv = \frac{6}{\pi} \times V$$

$$= \frac{6}{\pi} \times \text{volume of the sphere } x^2 + y^2 + z^2 = 9$$

$$= \frac{6}{\pi} \times \frac{4}{3}(\pi r^3), \text{ where } r = 3$$

$$= \frac{6}{\pi} \times \frac{4}{3}(\pi \times 3^3) = 216$$

Hence, the correct answer is 214 to 218.

Question Number: 14 **Question Type: MCQ**

Consider the following differential equation:

$$\frac{dy}{dt} = -5y; \text{ initial condition: } y = 2 \text{ at } t = 0.$$

The value of y at $t = 3$ is

(A) $-5e^{-10}$ (B) $2e^{-10}$

(C) $2e^{-15}$ (D) $-15e^2$

Solution: Given differential equation is

$$\frac{dy}{dt} = -5y \quad (1)$$

$$y = 2 \text{ at } t = 0 \quad (2)$$

From (1), $\frac{1}{y}\, dy = -5dt$

which is in variables separable form

Integrating on both sides

$$\int \frac{1}{y} dy = -\int 5dt$$

$$\Rightarrow \quad \ln y = -5t + c$$

$$\Rightarrow \quad y = e^{-5t} + c$$

$$\Rightarrow \quad y = c_1, e^{-5t} \quad (3),$$

where $c_1 = e^c$

From Eq. (2), $y = 2$ at $t = 0$

$$\Rightarrow \quad 2 = c_1\, e^{-5} \times 0 \Rightarrow c_1 = 2$$

Substituting the value of c_1 in Eq. (3), we have

$$y = 2e^{-5t}$$

The value of y at $t = 3$ is

$$y = 2e^{-5 \times 3} \Rightarrow y = 2e^{-15}.$$

Hence, the correct option is (C).

Question Number: 15 **Question Type: NAT**

The values of function $f(x)$ at 5 discrete points are given below:

x	0	0.1	0.2	0.3	0.4
$f(x)$	0	10	40	90	160

Using trapezoidal rule with step size of 0.1, the value of $\int_0^{0.4} f(x)dx$ is _____.

Solution:

x	0	0.1	0.2	0.3	0.4
$f(x)$	0	10	40	90	160

Here $h = 0.1$

By trapezoidal rule, we have

$$\int_0^{0.4} f(x)dx = \frac{h}{2}\,[f(x_0) + f(x_4) + 2(f(x_1) + f(x_2) + f(x_3))]$$

$$= \frac{0.1}{2}[(0 + 160) + 2(10 + 40 + 90)]$$

$$= \frac{1}{20}\,[160 + 280] = 22.$$

Hence, the correct answer is 21.8 to 22.2.

Question Number: 16 **Question Type: NAT**

The initial velocity of an object is 40 m/s. The acceleration a of the object is given by the following expression:

$$a = -0.1v,$$

where v is the instantaneous velocity of the object. The velocity of the object after 3 seconds will be _____.

Solution: $u = 40$ m/s and $V =$ Final velocity

$$a = -0.1 \text{ V}$$

We know that $a = \frac{dV}{dt}$ or $dt = \frac{dV}{a} \Rightarrow \int_0^t dt = -\int_u^V \frac{dV}{0.1V}$

$$\Rightarrow t = \frac{-1}{0.1}[\ln V]_u^V$$

$$\Rightarrow \quad -0.1t = [\ln V - \ln u]$$

At $t = 3$ seconds

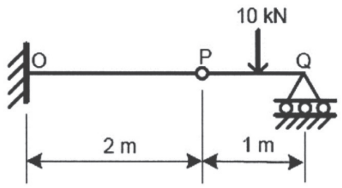
$$-(0.1 \times 3) = [\ln V - \ln 40]$$

$$\Rightarrow \quad V = 29.633 \text{ m/s}$$

Hence, the correct answer is 29.5 to 29.7.

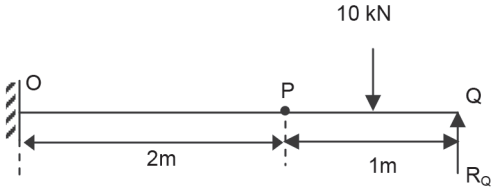
Question Number: 17 **Question Type: MCQ**

A cantilever beam OP is connected to another beam PQ with a pin joint as shown in the figure. A load of 10 kN is applied at the mid-point of PQ. The magnitude of bending moment (in kN-m) at fixed end O is



(A) 2.5 (B) 5
(C) 10 (D) 25

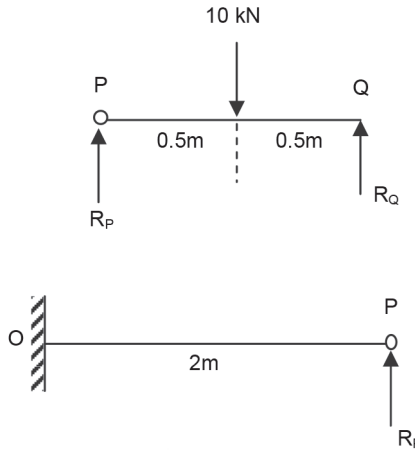
Solution:



$$M_a = 0$$

$$\Rightarrow \quad R_P \times 1 - 10 \times 0.5 = 0$$

$$\Rightarrow \quad R_P = 5 \text{ kN}$$



$$R_P = 5 \text{ kN}$$

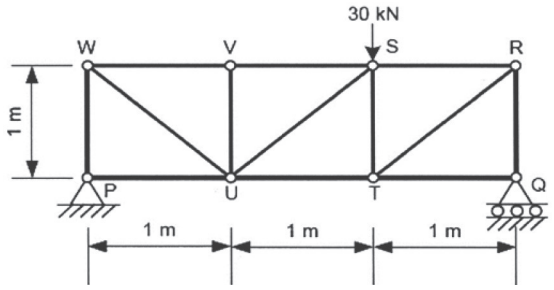
Bending moment at O, M_o

$$M_o = 5 \times 2 = 10 \text{ kN-m}$$

Hence, the correct option is (C).

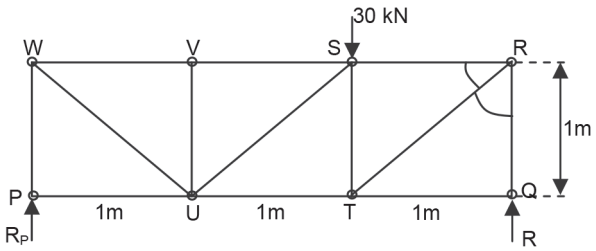
Question Number: 18 **Question Type: MCQ**

For the truss shown in the figure, the magnitude of the force (in kN) in the member SR is



(A) 10 (B) 14.14
(C) 20 (D) 28.28

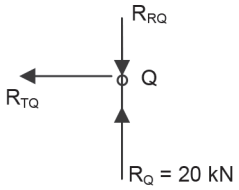
Solution:



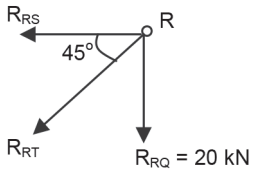
Taking moment about P, $M_P = 0$

$$R_a \times 3 - (30 \times 2) = 0 \Rightarrow R_Q = 20 \text{ kN}$$

$$\Sigma F_y = 0$$



$$\Rightarrow \quad R_{RQ} = 20 \text{ kN}$$



$$R_{RT} \sin 45^o = 20$$

$$\Rightarrow \quad R_{RT} = \frac{20}{\sin 45^o} \text{ and } R_{RT} \cos 45^o = R_{RS}$$

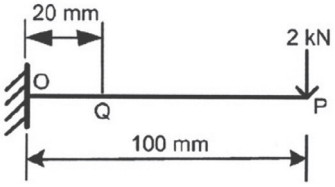
or $$R_{RS} = \frac{20}{\sin 45^o} \times \cos 45^o = 20 \text{ kN}$$

$\therefore$ Force on member SR, $R_{RS} = 20$ kN.

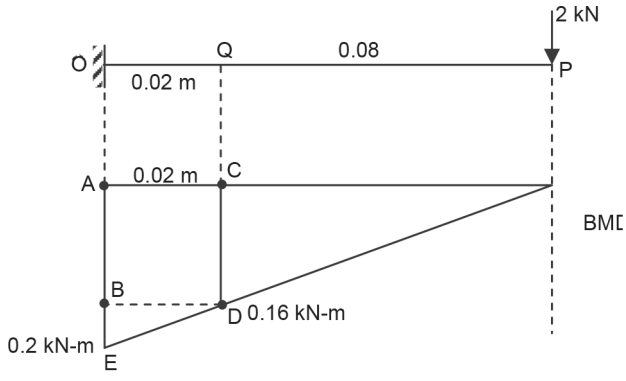
Hence, the correct option is (C).

Question Number: 19 **Question Type: NAT**

A cantilever beam with square cross-section of 6 mm side is subjected to a load of 2 kN normal to the top surface as shown in the figure. The Young's modulus of elasticity of the material of the beam is 210 GPa. The magnitude of slope (in radian) at Q (20 mm from the fixed end) is _____.



Solution:



Bending moment at $O = 2 \times 0.1 = 0.2$ kN-m

Bending moment at $Q = 2 \times 0.08 = 0.16$ kN-m

Taking C as origin, A as reference, and denoting θ as slope.

$\therefore \theta_C - \theta_A = \dfrac{1}{EI}$ [Area of bending moment diagram between C and A]

Now slope at fixed end A, $\theta_A = 0$

$$\therefore \quad \theta_C = \frac{1}{EI}\,[\text{Area of } \{BDE + ACDB\}]$$

$$\Rightarrow \theta_C = \frac{1\times10^3}{210\times10^9\times\dfrac{0.006^4}{12}}\left[\begin{matrix}\left\{\dfrac{1}{2}\times(0.2-0.16)\times0.02\right\}\\ +\{0.02\times0.16\}\end{matrix}\right]$$

$\Rightarrow \theta_C = 0.15873$ radians.

Hence, the correct answer is 0.15 to 0.17.

Question Number: 20 **Question Type: MCQ**

In a plane stress condition, the components of stress at a point are $\sigma_x = 20$ MPa, $\sigma_y = 80$ MPa, and $\tau_{xy} = 40$ MPa. The maximum shear stress (in MPa) at the point is

(A) 20 (B) 25

(C) 50 (D) 100

Solution: Given: $\sigma_x = 20$ MPa, $\sigma_y = 80$ MPa, $\tau_{xy} = 40$ MPa

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{20-80}{2}\right)^2 + 40^2}$$

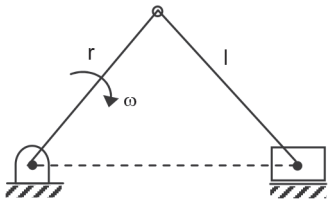
$\Rightarrow \tau_{max} = 50$ MPa.

Hence, the correct option is (C).

Question Number: 21 **Question Type: NAT**

In a certain slider-crank mechanism, lengths of crank and connecting rod are equal. If the crank rotates with a uniform angular speed of 14 rad/s and the crank length is 300 mm, the maximum acceleration of the slider (in m/s^2) is _____.

Solution:



$\omega = 14$ rad/s, $r = 0.3$ m $= l$, $n = \dfrac{l}{r} = 1$

Acceleration of the piston,

$$a = r\,\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

for maximum acceleration, $\dfrac{da}{d\theta} = 0$.

$$\therefore \quad -\sin\theta - \frac{2\sin2\theta}{n} = 0$$

$$\Rightarrow \quad \sin\theta + 2\sin\theta\cos\theta = 0$$

$$\Rightarrow \quad \sin\theta\,[1 + 2(\cos)\,\theta] = 0$$

$\therefore$ When $\sin\theta = 0$, $\theta = 0^o$ and

$$1 + 2\cos\theta = 0,\ \theta = \cos^{-1}\left(\frac{1}{2}\right)$$

$\therefore$ Acceleration will be maximum when $\theta = 0^o$

$$\therefore \quad (a)_{maximum} = 0.3 \times 14^2 \times \left[\cos 0^o + \frac{\cos 0^o}{n}\right]$$

$$\Rightarrow \quad (a)_{maximum} = 0.3 \times 14^2 \times 2$$

$$\Rightarrow \quad (a)_{maximum} = 117.6 \text{ m/s}^2$$

Hence, the correct answer is 115 to 120.

Question Number: 22 **Question Type: MCQ**

A slider-degree-freedom spring-mass system is subjected to a sinusoidal force of 10 N amplitude and frequency ω along the axis of the spring. The stiffness of the spring is 150 N/m, damping factor is 0.2 and the undamped natural frequency is 10 ω. At steady state, the amplitude of vibration (in m) is approximately

(A) 0.05 (B) 0.07

(C) 0.70 (D) 0.90

Solution: Given: $F_0 = 10$ N, $k = 150$ N/m, $\xi = 0.2$, $\omega_n = 10\,\omega$

$$\text{Amplitude, } A = \frac{F_o/k}{\sqrt{\left\{1-\left(\dfrac{\omega}{10\omega}\right)^2\right\}^2 + \left(\dfrac{2\xi\omega}{\omega_n}\right)^2}}$$

$$\Rightarrow A = \frac{10/150}{\sqrt{\left[1-\left(\dfrac{\omega}{10\omega}\right)^2\right]^2 + \left(\dfrac{2\times0.2\times\omega}{10\omega}\right)^2}}$$

$$\Rightarrow A = \frac{10/150}{\sqrt{\left(1-\dfrac{1}{100}\right)^2 + \left(\dfrac{2\times0.2}{10}\right)^2}}$$

$$\Rightarrow \quad A = 0.067 \text{ m or } A = 0.07 \text{ m}$$

Hence, the correct option is (B).

Question Number: 23 **Question Type: NAT**

A hollow shaft of 1 m length is designed to transmit a power of 30 kW at 700 rpm. The maximum permissible

angle of twist in the shaft is 1°. The inner diameter of the shaft is 0.7 times the outer diameter. The modulus of rigidity is 80 GPa. The outside diameter (in mm) of the shaft is _____.

Solution: Given: $L = 1$ m, $P = 30$ kW, $N = 700$ rpm, $\theta = 1$

$= 0.0174533$ radians, $d_i = 0.7\, d_o$, $G = 80$ GPa

$$P = \frac{2\pi NT}{60,000} \Rightarrow T = \frac{30\times 60,000}{2\times\pi\times 700}$$

$$\Rightarrow \quad T = 409.256 \text{ N-m}$$

Now $$\frac{T}{J} = \frac{G\theta}{L} \Rightarrow J = \frac{TL}{G\theta}$$

$$\therefore \frac{\pi}{32}\left[d_o^4 - d_i^4\right] = \frac{409.256\times 1}{80\times 10^9 \times 0.0174533}$$

$$\Rightarrow \quad d_o^4 - (0.7d_o)^4 = 2.9856 \times 10^{-6}$$

$$\Rightarrow \quad d_o = 0.04452 \text{ m or } d_o = 44.52 \text{ mm}$$

Hence, the correct answer is 43 to 45.

Question Number: 24 **Question Type: MCQ**

A hollow shaft ($d_o = 2d_i$ where d_o and d_i are the outer and inner diameters respectively) needs to transmit 20 kW power at 3000 RPM. If the maximum permissible shear stress is 30 MPa, d_o is

(A) 11.29 mm (B) 22.58 mm
(C) 33.87 mm (D) 45.16 mm

Solution: Given: $d_o = 2d_i$, $P = 20$ kW, $N = 3000$ rpm, $\tau_{max} = 30$ MPa

Now $$\frac{\tau}{r} = \frac{T}{J} \text{ or } \tau_{max} = \frac{T\times d_o/2}{\frac{\pi}{32}\left[d_o^4 - d_i^4\right]}$$

and $$P = \frac{2\pi NT}{60,000} \Rightarrow T = \frac{20\times 60,000}{2\times\pi\times 3000}$$

$$\Rightarrow \quad T = 63.662 \text{ N-m}$$

$$\therefore \tau_{max} = 30 \times 10^6 = \frac{63.662\times(2d_i)/2}{\frac{\pi}{32}\left[(2d_i)^4 - d_i\right]}$$

$$\Rightarrow d_i = \sqrt[3]{\frac{63.662\times 32}{\pi\times 30\times 10^6 \times 15}}$$

$$\Rightarrow \quad d_i = 0.01129 \text{ m}$$

$\therefore d_o = 2d_i = 2 \times 0.01129 = 0.02258$ m or $d_o = 22.58$ mm

Hence, the correct option is (B).

Question Number: 25 **Question Type: MCQ**

The total emissive power of a surface is 5000 W/m^2 at a temperature T_1 and 1200 W/m^2 at a temperature T_2, where the temperatures are in Kelvin. Assuming the emissivity of the surface to be constant, the ratio of the temperatures $\frac{T_1}{T_2}$ is

(A) 0.308 (B) 0.416
(C) 0.803 (D) 0.875

Solution: Emissive power (P) is proportional to the heat transfer

$$\Rightarrow \quad P \propto \in T^4$$

As emissivity of the surface is constant

$$\frac{P_1}{P_2} = \frac{T_1^4}{T_2^4} \Rightarrow \frac{T_1}{T_2} = \left(\frac{500}{1200}\right)^{0.25} = 0.803\,.$$

Hence, the correct option is (C).

Question Number: 26 **Question Type: MCQ**

The head loss for a laminar incompressible flow through a horizontal circular pipe is h_1. Pipe length and fluid remaining the same, if the average flow velocity doubles and the pipe diameter reduces to half its previous value, the head loss is h_2. The ratio h_2/h_1 is

(A) 1 (B) 4
(C) 8 (D) 16

Solution:

$$h_1 = \frac{f\,L V_1^2}{2g\,D_1}$$

Now $V_2 = 2V_1$ and $D_2 = D_1/2$ then

$$h_2 = \frac{f\,L(2V_1)^2}{2g(D_1/2)} \text{ and}$$

$$\frac{h_2}{h_1} = \frac{4\,f\,L V_1^2\times 2}{2g\,D_1} \times \frac{2gD_1}{f\,L V_1^2}$$

$$\Rightarrow \frac{h_2}{h_1} = 8$$

Hence, the correct option is (C).

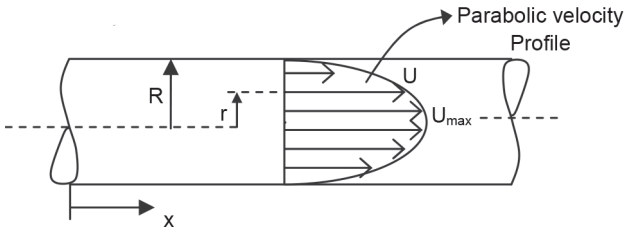
Question Number: 27 **Question Type: NAT**

For a fully developed laminar flow of water (dynamic viscosity 0.001 Pa-s) through a pipe of radius 5 cm, the axial pressure gradient is –10 Pa/m. The magnitude of axial velocity (in m/s) at a radial location of 0.2 cm is _____.

Solution:

Given: $\mu = 0.001$ Pa-s, $R = 0.05$ m

$$\left(\frac{\partial P}{\partial x}\right) = -10 \text{ Pa/m}$$



$$U_{max} = -\frac{1}{4\mu}\left(-\frac{\partial P}{\partial x}\right)R^2$$

$$\Rightarrow \quad U_{max} = \frac{-1}{(4\times 0.001)} \times (-10) \times 0.05^2$$

$$\therefore \quad U_{max} = 6.25 \text{ m/s}$$

Now velocity profile is $\frac{U}{U_{max}} = \left[1 - \frac{r^2}{R^2}\right]$

$$\therefore \quad (U)_{r=0.002m} = 6.25 \times \left[1 - \frac{0.002^2}{0.05^2}\right]$$

$$\Rightarrow \quad (U)_{r=0.002m} = 6.24 \text{ m/s}$$

Hence, the correct answer is 6.2 to 6.3.

Question Number: 28 **Question Type: MCQ**

A balanced counter flow heat exchanger has a surface area of 20 m^2 and overall heat transfer coefficient of 20 W/m^2-K. Air (C_p = 1000 J/kg-K) entering at 0.4 kg/s and 280 K is to be preheated by the air leaving the system at 0.4 kg/s and 300 K. The outlet temperature (in K) of the preheated air is

(A) 290 (B) 300
(C) 320 (D) 350

Solution: Energy balance equation

Energy lost = Energy gained

$$\therefore \quad m_1 C_p(T_f - T_1) = m_2 C_p (T_2 - T_f)$$

$$0.4 \times 1000 \times [T_f - 280] = 0.4 \times 1000 \times [300 - T_f]$$

$$\Rightarrow \quad T_f = 290 \text{ K}$$

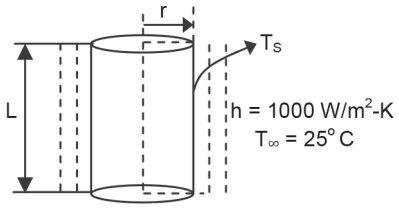
Hence, the correct option is (A).

Question Number: 29 **Question Type: MCQ**

A cylindrical uranium fuel rod of radius 5 mm in a nuclear reactor is generating heat at the rate of 4×10^7 W/m^3. The rod is cooled by a liquid (convective heat transfer coefficient 1000 W/m^2-K) at 25°C. At steady state, the surface temperature (in K) of the rod is

(A) 308 (B) 398
(C) 418 (D) 448

Solution:



Let T_s be the surface temperature and T_∞ be the temperature of liquid

$$\frac{\text{Heat generation}}{\text{Volume}} = \frac{\dot{q}}{m^3} = 4\times 10^7 \text{ W/m}^3$$

$$\therefore \quad \dot{q} = 4 \times 10^7 \times \pi \times r^2 \times L \text{ Watts}$$

$$\Rightarrow \quad \dot{q} = 4 \times 10^7 \times \pi \times 0.005^2 \times L = 1000\,\pi\, L\, W$$

$$\dot{q} = \frac{\Delta T}{(1/hA)} \Rightarrow 1000\,\pi\, L = \frac{T_S - T_\infty}{\frac{1}{1000(2\pi r L)}}$$

$$\therefore \quad T_S - 298 = 1000\,\pi\, L \times \frac{1}{1000\times 2\pi r L}$$

$$\Rightarrow \quad T_S = 398 \text{ K}$$

Hence, the correct option is (B).

Question Number: 30 **Question Type: NAT**

Work is done on a adiabatic system due to which its velocity changes from 10 m/s to 20 m/s, elevation increases by 20 m and temperature increases by 1 K. The mass of the system is 10 kg, C_v = 100 J/(kg.K) and gravitational acceleration is 10 m/s^2. If there is no change in any other component of the energy of the system, the magnitude of total work done (in kJ) on the system is _____.

Solution: Given: $C_1 = 10$ m/s, $C_2 = 20$ m/s, $z_2 - z_1 = 20$ m,

$$T_2 - T_1 = 1 \text{ K}$$

C_V = 100 J/kg-K, g = 10 m/s^2, $\delta Q = 0$

Assuming compressible fluid with $\gamma = 1$

$$\therefore \frac{C_P}{C_V} = 1 \Rightarrow C_p = 100 \text{ J/kg-K}$$

SFEE:

$$m\left[h_1 + \frac{C_1^2}{2000} + \frac{gz_1}{1000}\right] = m\left[h_2 + \frac{C_2^2}{2000} + \frac{gz_2}{1000}\right] + \delta W$$

$$\delta W = m\left[C_P(T_1 - T_2) + \frac{C_1^2 - C_2^2}{2000} + \frac{g(z_1 - z_2)}{1000}\right]$$

$$\Rightarrow \delta W = 10\left[0.1(-1) + \frac{\left(10^2 - 20^2\right)}{2000} + \frac{10(-20)}{1000}\right]$$

$$\Rightarrow \qquad \delta W = -4.5 \text{ kJ}$$

On the system, $\delta W = 4.5$ kJ

Hence, the correct answer is 4.5.

Question Number: 31 **Question Type: NAT**

One kg of air ($R = 287$ J/kg-K) undergoes an irreversible process between equilibrium state 1 (20°C, 0.9 m^3) and equilibrium state 2 (20°C, 0.6 m^3). The change in entropy $s_2 - s_1$ (in J/kg-K) is _____.

Solution: $Tds = dU + p\,dV$

or $$\triangle S = m\,C_V \ln\frac{T_2}{T_1} + mR\ln\frac{V_2}{V_1}$$

$$\triangle S = 0 + 1 \times 287 \times \ln\frac{0.6}{0.9}$$

$$\Rightarrow \qquad \triangle S = -116.37 \text{ J/kg-K}$$

Hence, the correct answer is –117 to –115.

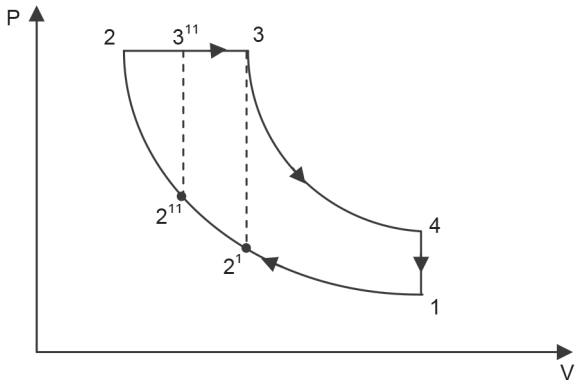
Question Number: 32 **Question Type: MCQ**

For the same values of peak pressure, peak temperature, and heat rejection, the correct order of efficiencies for Otto, Dual, and Diesel cycles is

(A) $\eta_{Otto} > \eta_{Dual} > \eta_{Diesel}$ (B) $\eta_{Diesel} > \eta_{Dual} > \eta_{Otto}$

(C) $\eta_{Dual} > \eta_{Diesel} > \eta_{Otto}$ (D) $\eta_{Diesel} > \eta_{Otto} > \eta_{Dual}$

Solution: For same peak pressure, peak temperature, and heat rejection, the P-V plot is



$1 - 2 - 3 - 4 \rightarrow$ Diesel cycle

$1 - 2^1 - 3 - 4 \rightarrow$ Otto cycle

$1 - 2^{11} - 3^{11} - 4 \rightarrow$ Dual cycle.

Here $$(W_{net})_{diesel} > (W_{net})_{dual} > (W_{net})_{otto}$$

$\therefore$ $$\eta_{diesel} > \eta_{dual} > \eta_{otto}$$

Hence, the correct option is (B).

Question Number: 33 **Question Type: NAT**

In a Rankine cycle, the enthalpies at turbine entry and outlet are 3159 kJ/kg and 2187 kJ/kg, respectively. If the specific pump work is 2 kJ/kg, the specific steam consumption (in kg/kW-h) of the cycle based on net output is _____.

Solution: $W_{net} = (3159 - 2187) - 2 = 970$ kJ/kg

$\therefore$ Specific steam consumption, SSC

$$= \frac{3600}{W_{net}} = \frac{3600}{970} = 3.711 \frac{\text{kg}}{\text{kW-h}}$$

Hence, the correct answer is 3.6 to 3.8.

Question Number: 34 **Question Type: NAT**

A cube and a sphere made of cast iron (each of volume 1000 cm^3) were cast under identical conditions. The time taken for solidifying the cube was 4 s. The solidification time (in s) for the sphere is _____.

Solution: Solidification time $t = k\left(\frac{V}{S}\right)^2$

$V =$ Volume, $S =$ Surface area, $k =$ Material constant

Cube of 1000 cm^3 $\Rightarrow$ Side of cube $= a = 10$ cm

$\therefore$ $$S = 6 \times 10^2 = 600 \text{ cm}^2$$

$\therefore$ $$t_{cube} = 4 = k\left(\frac{1000}{600}\right)^2 \Rightarrow k = \frac{36}{25}\frac{\text{sec}}{\text{m}^2}.$$

$$t_{sphere} = k.\left(\frac{V}{S}\right)^2$$

$$V = 1000 \text{ cm}^3 = \frac{4}{3}\,\pi r^3 \Rightarrow r = 6.203 \text{ cm}.$$

$$S = 4\,\pi r^2 = 483.597 \text{ cm}^2.$$

$\therefore$ $$t_{sphere} = \frac{36}{25} \times \left(\frac{1000}{483.597}\right)^2 = 6.157 \text{ sec}$$

Hence, the correct answer is 6.0 to 6.3.

Question Number: 35 **Question Type: MCQ**

In a two-stage wire drawing operation, the fractional reduction (ratio of change in cross-sectional area to initial cross-sectional area) in the first stage is 0.4. The fractional reduction in the second stage is 0.3. The overall fractional reduction is

(A) 0.24 (B) 0.58

(C) 0.60 (D) 1.00

Solution: First stage, $\frac{\Delta A}{A_0} = 0.4$

$$\frac{A_0 - A_1}{A_0} = 0.4 \Rightarrow \frac{A_1}{A_0} = 0.6\,.$$

Second stage

$$\frac{\Delta A}{A_1}=\frac{A_1-A_2}{A_1}=0.3\Rightarrow\frac{A_2}{A_1}=0.7$$

$$\text{Overall fractional reduction}=\frac{A_0-A_2}{A_0}=1-\frac{A_2}{A_0}$$

$$\frac{A_2}{A_0}=\frac{A_2}{A_1}\times\frac{A_1}{A_0}=0.7\times0.6=0.42$$

$$\therefore\quad 1-\frac{A_2}{A_0}=1-0.42=0.58$$

Hence, the correct option is (B).

Question Number: 36 **Question Type: NAT**

The flow stress (in MPa) of a material is given by

$$\sigma=500\in^{0.1},$$

where ε is true strain. The Young's modulus of elasticity of the material is 200 GPa. A block of thickness 100 mm made of this material is compressed to 95 mm thickness and then the load is removed. The final dimension of the block (in mm) is _____.

Solution: $E=200\ \text{GP}_a$

$$\text{Strain}=\frac{\Delta l}{l}=\frac{5}{100}=0.05$$

$$\text{True strain}\in_t=\ln(1+\in)=\ln(1.05)=0.0488$$

$$\therefore\quad \text{Stress}=\sigma=500\times\in_t^{0.1}=369.67\ \text{MPa}$$

$$E=\frac{\sigma}{\in}\Rightarrow\in=\frac{369.67\times10^6}{200\times10^6}=1.8483\times10^{-3}$$

∴ Change in length after removal of load = 0.18483 mm

∴ Final dimension of the block = 95 + 0.18483 = 95.18483 mm

Hence, the correct answer is 95.14 to 95.20.

Question Number: 37 **Question Type: MCQ**

During a TIG welding process, the arc current and arc voltage were 50 A and 60 V, respectively, when the welding speed was 150 mm/min. In another process, the TIG welding is carried out at a welding speed of 120 mm/min at the same arc voltage and heat input to the material so that weld quality remains the same. The welding current (in A) for this process is

(A) 40.00 (B) 44.72
(C) 55.90 (D) 62.25

Solution: Heat input and voltage are same for both processes

$$Q=VIt$$

$t=\frac{L}{u}$, L = length of weld, u = welding speed.

$$\therefore\quad Q_1=Q_2\Rightarrow\frac{I_1L_1}{u_1}=\frac{I_2L_2}{u_2}$$

Taking $L_1=L_2$

$$\therefore\quad\frac{50}{150}=\frac{I_2}{120}\Rightarrow I_2=40\ \text{Amp}$$

Hence, the correct option is (A).

Question Number: 38 **Question Type: MCQ**

A single point cutting tool with 0° rake angle is used in an orthogonal machining process. At a cutting speed of 180 m/min, the thrust force is 490 N. If the coefficient of friction between the tool and the chip is 0.74, then the power consumption (in kW) for the machining operation is _____.

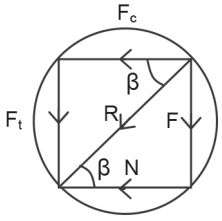
Solution: Power consumption $=F_c\times V$

F_c = cutting force, F_t = thrust force = 490 N

Part of Merchant's circle is:

$$\tan\beta=\mu=0.7$$

$$\Rightarrow\quad\beta=35^o$$



$$\therefore\quad F_C=F_t/\tan\beta=490/0.7=700\ \text{N}$$

$$\text{Power consumption}=700\times\frac{180}{60}=2100\ \text{W}$$
$$=2.1\ \text{kW}$$

Hence, the correct answer is 2.0 to 2.2.

Question Number: 39 **Question Type: MCQ**

A resistance–capacitance relaxation circuit is used in an electrical discharge machining process. The discharge voltage is 100 V. At spark cycle time of 25 μs, the average power input required is 1 kW. The capacitance (in μF) in the circuit is

(A) 2.5 (B) 5.0
(C) 7.5 (D) 10.0

Solution: Discharge Voltage, $V_d=100$ V

Cycle time, $t=25$ μs

$P_{avg}=1$kW, capacitance $=C$

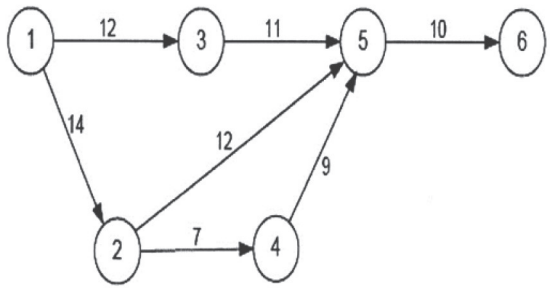
$$E = \frac{1}{2} C V_d^2 = \frac{1}{2} \times C \times 100^2$$

$$P = \frac{E}{t} 1000 = \frac{\frac{1}{2} \times C \times 100^2}{25 \times 10^{-6}} \Rightarrow C = 5\ \mu F$$

Hence, the correct option is (B).

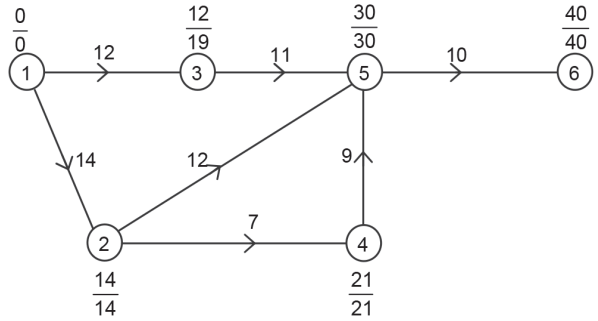
Question Number: 40 **Question Type: NAT**

A project consists of 7 activities. The network along with the time durations (in days) for various activities is shown in the figure.



The minimum time (in days) for completion of the project is _____.

Solution:



The minimum duration for completion is the critical path time = 40 days

Hence, the correct answer is 39 to 40.

Question Number: 41 **Question Type: NAT**

A manufacturer has the following data regarding a product.

Fixed cost per month = Rs. 50,000

Variable cost per unit = Rs. 200

Selling price per unit = Rs. 300

Production capacity = 1500 units per month

If the production is carried out at 80% of the rated capacity, then the monthly profit (in ₹) is _____.

Solution: Fixed cost per month = ₹ 50,000 (FC)

Variable cost per unit = ₹ 200 (V)

Selling price per unit = ₹ 300 (S)

Production capacity = 1500 units/month

Production = 80% of rated capacity.

$\therefore$ Production = $1500 \times 0.8 = 1200$ units/month

$\therefore$ Selling price = $S = 1200 \times 300 =$ ₹ 3,60,000

Variable cost = $V = 1200 \times 200 =$ ₹ 2,40,000

$\therefore$ Profit = $S - (V + FC)$

$= 3,60,000 - (2,40,000 + 50,000)$

Profit = ₹70,000

Hence, the correct answer is 68000 to 72000.

Question Number: 42 **Question Type: MCQ**

At least one eigenvalue of a singular matrix is

(A) positive (B) zero

(C) negative (D) imaginary

Solution: We know that the determinant of a matrix A is equal to the product of the eigen values of A

If a matrix A is a singular matrix, then determinant of $A = 0$

$\Rightarrow$ The product of the eigen values of $A = 0$

$\Rightarrow$ At least one eigen value must be 0.

Hence, the correct option is (B).

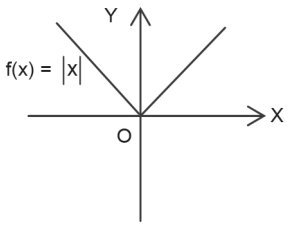
Question Number: 43 **Question Type: MCQ**

At $x = 0$, the function $f(x) = |x|$ has

(A) a minimum (B) a maximum

(C) a point of inflexion (D) neither a maximum nor minimum

Solution:



From the graph of $f(x) = |x|$, $f(x)$ has a minimum at $x = 0$.

Hence, the correct option is (A).

Question Number: 44 **Question Type: MCQ**

Curl of vector $V(x, y, z) = 2x^2\,\boldsymbol{i} + 3z^2\,\boldsymbol{j} + y^3\,\boldsymbol{k}$ at $x = y = z = 1$ is

(A) $-3\boldsymbol{i}$ (B) $3\boldsymbol{i}$

(C) $3\boldsymbol{i} - 4\boldsymbol{j}$ (D) $3\boldsymbol{i} - 6\boldsymbol{k}$

Solution: Given $\bar{V}(x, y, z) = 2x^2\ \bar{i} + 3z^2\ \bar{j} + y^3\ \bar{k}$

$$\text{curl } \bar{V} = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 2x^2 & 3z^2 & y^3 \end{vmatrix}$$

$$= (3y^2 - 6z)\ \bar{i} - (0 - 0)\ \bar{j} + (0 - 0)\ \bar{k}$$

$\therefore$ curl $\bar{V} = (3y^2 - 6z)\ \bar{i}$

curl $\bar{V}$ when $x = y = z = 1$ is $(3(1)^2 - 6 \times 1)\ \bar{i}$

$= -3\bar{i}$.

Hence, the correct option is (A).

Question Number: 45 **Question Type: MCQ**

The Laplace transform of e^{i5t} where $i = \sqrt{-1}$ is

(A) $\frac{s-5i}{s^2-25}$ (B) $\frac{s+5i}{s^2+25}$

(C) $\frac{s+5i}{s^2-25}$ (D) $\frac{s-5i}{s^2+25}$

Solution: We have $L[e^{i5t}] = L[\cos 5t + i \sin 5t]$

$$= L[\cos 5t] + i\, L[\sin 5t]$$

$$= \frac{s}{s^2+5^2} + i\left(\frac{5}{s^2+5^2}\right)$$

$$= \frac{s+5i}{s^2+25}.$$

Hence, the correct option is (B).

Question Number: 46 **Question Type: NAT**

Three vendors were asked to supply a very high precision component. The respective probabilities of their meeting the strict design specifications are 0.8, 0.7, and 0.5. Each vendor supplies one component. The probability that out of total three components supplied by the vendors, at least one will meet the design specification is _____.

Solution: Let V_1, V_2, and V_3 be the three vendors, who were asked to supply a very high precision component.

Let A, B, and C be the events of the components supplied by V_1, V_2, and V_3 respectively, meeting the strict design specifications.

$\therefore$ $P(A) = 0.8$, $P(B) = 0.7$ and $P(C) = 0.5$

Probability that at least one of the three components will meet the design specifications

$$= P(A \cup B \cup C) = 1 - P\left(\overline{A \cup B \cup C}\right)$$

$$= 1 - P\left(\bar{A} \cap \bar{B} \cap \bar{C}\right)$$

$$= 1 - P\left(\bar{A}\right) P\left(\bar{B}\right) P\left(\bar{C}\right)$$

($\because$ A, B, and C are independent)

$$= 1 - 0.2 \times 0.3 \times 0.5$$

$$= 1 - 0.03$$

$$= 0.97.$$

Hence, the correct answer is 0.96 to 0.98.

Question Number: 47 **Question Type: NAT**

A small ball of mass 1 kg moving with a velocity of 12 m/s undergoes a direct central impact with a stationary ball of mass 2 kg. The impact is perfectly elastic. The speed (in m/s) of 2 kg mass ball after the impact will be _____.

Solution: For perfectly elastic impact, coefficient of restitution is 1.

$$e = 1 = \frac{v_2 - v_1}{u_1 - u_2}$$

u_1, u_2 – initial and final velocities of mass 1 kg.

v_1, v_2 – initial and final velocities of mass 2 kg.

$$u_1 = 12 \text{ m/s}, v_1 = 0$$

$\therefore$ $u_1 - u_2 = v_2 - v_1$

$12 - u_2 = v_2 \Rightarrow u_2 = 12 - v_2$

Conservation of kinetic energy:

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 v_1^2 = \frac{1}{2} m_1 u_2^2 + \frac{1}{2} m_2 v_2^2$$

$$\Rightarrow u_1^2 = u_2^2 + 2v_2^2 \Rightarrow 12^2 = (12 - v_2)^2 + 2\, v_2^2$$

$\therefore$ $v_2 = 8$ m/s.

Hence, the correct answer is 7.8 to 8.2.

Question Number: 48 **Question Type: NAT**

A rod is subjected to a uni-axial load within linear elastic limit. When the change in the stress is 200 MPa, the change in the strain is 0.001. If the Poisson's ratio of the rod is 0.3, the modulus of rigidity (in GPa) is _____.

Solution: Young's modulus, $E = \frac{\sigma}{\in} = \frac{200}{0.001} = 200$ GPa

$$E = 2G(1 + \mu) \Rightarrow 200 = 2G(1 + 0.3)$$

$\Rightarrow$ $G = 76.923$ GPa

Hence, the correct answer is 76 to 78.

Question Number: 49 **Question Type: MCQ**

A gas is stored in a cylindrical tank of inner radius 7 m and wall thickness 50 mm. The gage pressure of the gas is 2 MPa. The maximum shear stress (in MPa) in the wall is

(A) 35 (B) 70

(C) 140 (D) 280

Solution: Given: $D = 14$ m, $t = 0.05$ m, $P = 2$ MPa

$$\sigma_1 = \sigma_h = \frac{PD}{2t}$$

$$\sigma_2 = \sigma_L = \frac{PD}{4t}$$

Maximum inplane shear stress, $\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$

$$\Rightarrow \quad \tau_{max} = \frac{PD}{8t} = \frac{2\times14}{8\times0.05}$$

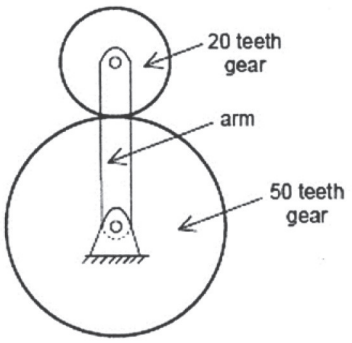
$$\Rightarrow \quad \tau_{max} = 70 \text{ MPa}$$

Absolute shear stress, $(\tau_{max})_{abs} = \frac{\sigma_1}{2} = \frac{PD}{4t}$

$$\Rightarrow (\tau_{max})_{abs} = \frac{2\times14}{4\times0.05} = 140 \text{ MPa}$$

Hence, the correct option is (C).

Question Number: 50 **Question Type: MCQ**



The number of degrees of freedom of the planetary gear train shown in the figure is

(A) 0 (B) 1
(C) 2 (D) 3

Solution: To define the position of any gear or arm in the system of planetary gears completely the rotation of one gear and the arm are required.

$\therefore$ The degree of freedom $= 2$

Hence, the correct option is (C).

Question Number: 51 **Question Type: NAT**

In a spring-mass system, the mass is m and the spring constant is k. The critical damping coefficient of the system is 0.1 kg/s. In another spring-mass system, the mass is $2m$ and the spring constant is $8k$. The critical damping coefficient (in kg/s) of this system is _____.

Solution: Critical damping coefficient, $C_C = 2 \times \omega_n \times m$

or $C_C = 2\sqrt{km} = 0.1$ kg/s

Now $m_1 = 2m, k_1 = 8$k

$$(C_C)_1 = 2\sqrt{k_1 m_1} = 2\sqrt{2m(8k)}$$

$$\Rightarrow \quad (C_C)_1 = (2\sqrt{km}) \times 4 = 4\, C_C$$

$$\Rightarrow \quad (C_C)_1 = 4 \times 0.1 = 0.4 \text{ kg/s}$$

Hence, the correct answer is 0.38 to 0.42.

Question Number: 52 **Question Type: NAT**

The uniaxial yield stress of a material is 300 MPa. According to Von Mises criterion, the shear yield stress (in MPa) of the material is _____.

Solution: According to Von-mises theory

$$S_{yt} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2} \text{ and, } \sigma_1 = -\sigma_2 = \tau_{xy} \text{ and } \sigma_3 = 0$$

Putting value of σ_1 and σ_2, we get

$$S_{yt} = \sqrt{3\tau_{xy}^2}$$

$$\Rightarrow \quad S_{yt} = \sqrt{3}\,\tau_{xy}$$

Replacing τ_{xy} by S_{sy} we get

$$S_{sy} = \frac{S_{yt}}{\sqrt{3}} = \frac{300}{\sqrt{3}} = 173.2$$

Hence, the correct answer is 171 to 175.

Question Number: 53 **Question Type: MCQ**

If the fluid velocity for a potential flow is given by $V(x, y) = u(x, y)i + v(x, y)j$ with usual notations, then the slope of the potential line at (x, y) is

(A) $\frac{v}{u}$ (B) $-\frac{u}{v}$
(C) $\frac{v^2}{u^2}$ (D) $\frac{u}{v}$

Solution: The fluid velocity for the potential flow

$$= \bar{V}\ (x, y) = u(x, y)\ \bar{i} + v\,(x, y)\ \bar{j}$$

As $\bar{V}$ is irrotational, there exists a scalar point function $\varphi\,(x, y)$ such that

$$\bar{V} = \nabla\varphi$$

$$\Rightarrow \quad u(x, y)\ \bar{i} + v\,(x, y)\ \bar{j} = \frac{\partial\varphi}{\partial x}\,\bar{i} + \frac{\partial\varphi}{\partial y}\,\bar{j}$$

$$\Rightarrow \quad \frac{\partial\varphi}{\partial x} = u \text{ and } \frac{\partial\varphi}{\partial y} = v \qquad (2)$$

where $\varphi(x, y) = c$ are known as potential lines.

The slope of the potential line $= \dfrac{dy}{dx} = \dfrac{-\left(\dfrac{\partial \varphi}{\partial x}\right)}{\left(\dfrac{\partial \varphi}{\partial y}\right)}$

$= \dfrac{-u}{v}.$

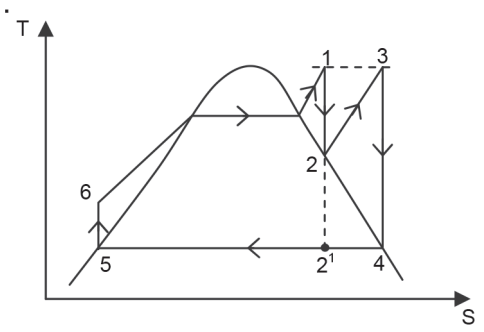
Hence, the correct option is (B).

Question Number: 54 **Question Type: MCQ**

Which of the following statements regarding a Rankine cycle with reheating are TRUE?

(i) increase in average temperature of heat addition.
(ii) reduction in thermal efficiency
(iii) drier steam at the turbine exit
(A) only (i) and (ii) are correct
(B) only (ii) and (iii) are correct
(C) only (i) and (iii) are correct
(D) (i), (ii), and (iii) are correct

Solution:



$x_4 > x_2{}^1 \rightarrow$ Dryness fraction increases at turbine exit.

Therefore, drier steam at the turbine exits and there is increase in average temperature of heat addition.

Hence, the correct option is (C).

Question Number: 55 **Question Type: MCQ**

Within a boundary layer for a steady incompressible flow, the Bernoulli equation

(A) holds because the flow is steady
(B) holds because the flow is incompressible
(C) holds because the flow is transitional
(D) does not hold because the flow is frictional

Solution: Assumption made in Bernoulli's equation

(a) The flow is ideal, i.e., viscosity is zero.
(b) The flow is steady.
(c) The flow is incompressible.
(d) The flow is irrotational.

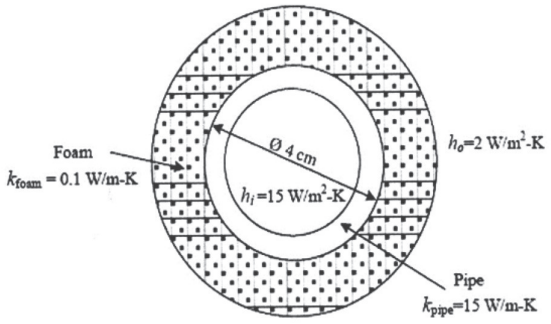
If any one of the assumption is not satisfied, then the Bernoulli's equation does not hold.

In boundary layer, the flow is viscous or not ideal and hence Bernoulli's equation does not hold.

Hence, the correct option is (D).

Question Number: 56 **Question Type: NAT**

If a foam insulation is added to a 4 cm outer diameter pipe as shown in the figure, the critical radius of insulation (in cm) is _____.



Solution: The critical radius of insulation $= r_c = \dfrac{k}{h}$

where, $k = 0.1$ W/m-K and $h = 2$ W/m^2–k

$\therefore \quad r_c = \dfrac{0.1}{2} = 0.05 \text{ m} = 5 \text{ cm}$

Hence, the correct answer is 4.9 to 5.1.

Question Number: 57 **Question Type: MCQ**

In the laminar flow of air ($Pr = 0.7$) over a heated plate, if δ and δ_T denote, respectively, the hydrodynamic and thermal boundary layer thickness, then

(A) $\delta = \delta_T$ (B) $\delta > \delta_T$
(C) $\delta < \delta_T$ (D) $\delta = 0$ but $\delta_T \neq 0$

Solution: $\dfrac{\delta}{\delta_t} = P_r^{1/3} \Rightarrow \delta = (0.7)^{1/3}\ \delta_t$

$\Rightarrow \quad \delta = 0.8879\ \delta_t$

$\therefore \quad \delta < \delta_t$

Hence, the correct option is (C).

Question Number: 58 **Question Type: NAT**

The *COP* of a Carnot heat pump operating between 6°C and 37°C is _____.

Solution: $COP = \dfrac{(37+273)}{[(37+273)-(6+273)]} = 10$

Hence, the correct answer is 9.8 to 10.2.

Question Number: 59 **Question Type: MCQ**

The Vander Waals equation of state is

$$\int \left[p + \frac{a}{v^2}\right](v - b) = RT.$$

where p is the pressure, v is the specific volume, T is the temperature, and R is the characteristic gas constant. The SI unit of a is

(A) J/kg-K (B) m^3/kg
(C) m^5/kg-s^2 (D) Pa/kg

Solution: $\left[p+\frac{a}{\nu^2}\right](\nu-b)=RT$

SI Units:

$p = kN/m^2$, $\nu = m^3/kg$

$T = k$, $R = kJ/kg\text{-}K$

Now $$p(\nu-b)+\frac{a(\nu-b)}{\nu^2}=RT$$

$$\Rightarrow \frac{kN}{m^2}\times\left(\frac{m^3}{kg}\right)+\frac{a\left(m^3/kg\right)}{\left(m^3/kg\right)^2}=\frac{kJ}{kg\text{-}K}\times K$$

$\therefore$ The unit of $\frac{a}{\left(m^3/kg\right)}$ should be equal to kJ/kg

$$\frac{a}{\left(m^3/kg\right)}=\frac{kJ}{kg}\Rightarrow\frac{a}{\left(m^3/kg\right)}=\frac{kN\text{-}m}{kg}$$

$$\Rightarrow a=\frac{kN\text{-}m}{kg}\times\frac{m^3}{kg}=\frac{kN\text{-}m^4}{kg^2}$$

or $$a=\left(kg\times\frac{m}{s^2}\right)\times\frac{m^4}{kg^2}\Rightarrow a=\frac{m^5}{kg\text{-}s^2}$$

Hence, the correct option is (C).

Question Number: 60 **Question Type: NAT**

A rope-brake dynamometer attached to the crank shaft of an I.C. engine measures a brake power of 10 kW when the speed of rotation of the shaft is 400 rad/s. The shaft torque (in N-m) sensed by the dynamometer is _____.

Solution: Power = Torque × Angular speed

$\Rightarrow \quad 10 \times 10^3 = T \times 400$

$\Rightarrow \quad T = 25$ N-m

Hence, the correct answer is 24 to 26.

Question Number: 61 **Question Type: NAT**

The atomic packing factor for a material with body centered cubic structure is _____.

Solution: APF = Atomic Packing Factor = $\frac{V_{UC}}{V_{atoms}}$

V_{UC} = Volume of unit cell

V_{atoms} = Volume of atoms in a unit cell

In BCC (body center cubic),

No. of atoms per unit cell = 2

Edge length of cube, $a=\frac{4}{\sqrt{3}}r$

where r is the radius of the atom.

$$\therefore \text{APF of BCC} = \frac{a^3}{2\times\frac{4}{3}\pi r^3}=\frac{\left(\frac{4}{\sqrt{3}}r\right)^3}{\frac{8}{3}\pi r^3}=0.68$$

Hence, the correct answer is 0.66 to 0.69.

Question Number: 62 **Question Type: MCQ**

The primary mechanism of material removal in electro chemical machining (ECM) is

(A) chemical corrosion (B) etching
(C) ionic dissolution (D) spark erosion

Solution: In electrochemical machining is the reverse process of electroplating. Due to high rate of electrolyte movement in between the tool work piece gap, the metal ions are washed away.

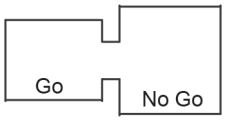
Hence, the correct option is (C).

Question Number: 63 **Question Type: MCQ**

Which one of the following statements is TRUE?

(A) The 'GO' gage controls the upper limit of a hole.
(B) The 'NO GO' gage controls the lower limit of a shaft.
(C) The 'GO' gage controls the lower limit of a hole.
(D) The 'NO GO' gage controls the lower limit of a hole.

Solution:



Plug gage

A plug gage is used to measure holes. The Go gage measures the lower limit and the No Go gage measures the upper limit.

Hence, the correct option is (C).

Question Number: 64 **Question Type: MCQ**

During the development of a product, an entirely new process plan is made based on design logic, examination of geometry, and tolerance information. This type of process planning is known as

(A) retrieval (B) generative
(C) variant (D) group technology based

Solution: The two approaches of computer aided process planning are:

(1) Variant
(2) Generative

Variant approach involves retrieving existing plan for a similar part and making modifications.

Generative approach involves generation of new process plans by means of decision logic and process knowledge.

Hence, the correct option is (B).

Question Number: 65 **Question Type: NAT**

Annual demand of a product is 50,000 units and the ordering cost is ₹ 7000 per order. Considering the basic economic order quantity model, the economic order quantity is 10,000 units. When the annual inventory cost is minimized, the annual inventory holding cost (in ₹) is _____.

Solution: $D = 50{,}000$ units/year

Ordering cost $C_0 = ₹\ 7000$/ order

$$EOQ = q = 10{,}000 \text{ units}$$

For optimal annual inventory cost

$$\text{Inventory holding cost} = \frac{D}{q}C_o = \frac{50{,}000}{10{,}000} \times 7000$$

$$= ₹\ 35{,}000$$

Hence, the correct answer is 34,000 to 36,000.