Detailed Analysis of GATE 2016 Paper

GATE ME Solved 2016 Paper (Set 1) Detailed Analysis

Subject	Topic	1 Mark Questions	2 Marks Questions	Total Questions	Total Marks
General Aptitude	Numerical Ability	2	4	6	10
	Verbal Ability	3	2		5
Total marks					**15**
Engineering Maths	Linear Algebra	1		1	1
	Differential Equations	1	1	2	3
	Complex Variables	1	1	2	3
	Probability	1		1	1
	Numerical Methods	1	1	2	3
	Calculus		1	1	2
Total marks					**13**
Strength of Materials	Torsion of Shafts	1	0	1	1
	Deflection of Beam	1	0	1	1
	Properties of Metals	1	1	2	3
	Stress and Strain	0	1	1	2
	Moment of Inertia	0	1	1	2
	Shear Force and Bending Moment	0	1	1	2
	Prinicipal Stresses and Strains	0	1	1	2
Total Marks					**13**
Theory of Machines	Gyroscope	1	0	1	1
	Vibration	1	1	2	3
	Dynamic Analysis of Linkages	0	1	1	2
	Gear Trains	0	1	1	2
Total Marks					**8**
Machine Design	Springs	1	0	1	1
Total Marks					**1**
Thermodynamics	First Law of Thermodynamics	1	1	2	3
	I.C. Engines	1	0	1	1
	Vapour Power Cycle	1	1	2	3
	Thermodynamic Relations	0	1	1	2
	Properties of Pure Substances	0	1	1	2
Total Marks					**11**
Fluid Mechanics & Machinary	Fluid Kinematics	1	0	1	1
	Buoyancy	1	0	1	1
	Hydaulic Turbine	1	0	1	1
	Manometry	0	1	1	2
	Dimensional Analysis	0	1	1	2
	Boundary Layer Theory	0	1	1	2
Total Marks					**9**

Manufacturing Technology	Welding	1	0	1	1
	Metal Casting	1	1	2	3
	Non-traditional Machining	1	0	1	1
	Metal Cutting	1	1	2	3
	Metrology	1	0	1	1
	Metal Forming	0	1	1	2
	CIM	0	1	1	2
Total Marks					**13**
Industrial Engineering	Inventory Control		1	1	2
	Linear Programming		1	1	2
Total Marks					**4**
Heat and Mass Transfer	Conduction	1	0	1	1
	Transient Conduction	0	1	1	2
	Radiation	0	1	1	2
	Convection	0	1	1	2
Total Marks					**7**
Engineering Mechanics	FBD and Equilibrium	1	0	1	1
	Kinematics of Bodies	1	0	1	1
	Friction	0	1	1	2
	Trusses	0	1	1	2
Total Marks					**6**

GATE ME Solved 2016 Paper (Set 2) Detailed Analysis

Subject	Topic	1 Mark Questions	2 Marks Questions	Total Questions	Total Marks
General Aptitude	Numerical Ability	2	4	6	10
	Verbal Ability	3	2	5	5
Total marks					**15**
Engineering Maths	Linear Algebra	1		1	1
	Calculus	1	1	2	3
	Differential Equations	1		1	1
	Complex Variables	1	1	2	3
	Numerical Methods	1	1	2	3
	Probability		1	1	2
Total marks					**13**
Strength of materials	Prinicipal stresses and strains	2	0	2	2
	Thin cylinders	1	0	1	1
	Stress and strain	1	2	3	5
	Deflection of beam	0	2	2	4
Total Marks					**12**
Theory of Machines	Vibration	1	1	2	3
	Velocity Analysis	0	1	1	2
Total Marks					**5**

Machine Design	Brakes	2	0	2	2
	Design Against Static Load	0	1	1	2
Total Marks					**4**
Thermodynamics	First Law of Thermodynamics	1	1	2	3
	Gas Turbine	1	0	1	1
	Second Law of Thermodynamics	1	1	2	3
	RAC	0	2	2	4
Total Marks					**11**
Fluid mechanics & machinary	Fluid Kinematics	1	0	1	1
	Manometry	1	0	1	1
	Buoyancy	0	2	2	4
	Viscous Flow	0	1	1	2
Total Marks					**8**
Manufacturing Technology	Engg. Material	1	1	2	3
	Welding	1	1	2	3
	Metal Cutting	1	1	2	3
	Non-traditional Machining	1	1	2	3
	Metal Casting	0	1	1	2
	Metrology	0	1	1	2
Total Marks					**16**
Industrial Engineering	Inventory Control	0	1	1	2
	PERT/CPM	0	1	1	2
	Queuing Theory	1	0	1	1
Total Marks					**5**
Heat and Mass Transfer	Conduction	1	0	1	1
	Radiation	1	0	1	1
	Heat Exchangers	0	1	1	2
	Transient Conduction	0	1	1	2
Total Marks					**6**
Engineering Mechanics	Momentum	1	1	2	3
	FBD and Equilibrium		1	1	2
Total Marks					**5**

GATE ME Solved 2016 Paper (Set 3) Detailed Analysis

Subject	Topic	1 Mark Questions	2 Marks Questions	Total Questions	Total Marks
General Aptitude	Numerical Ability	2	4	6	10
	Verbal Ability	3	2		5
Total marks					**15**
Engineering Maths	Linear Algebra	1	1	2	3
	Calculus	1	2	3	5
	Differential Equations	1		1	1
	Probability	1	1	2	3
	Numerical Methods	1		1	1
Total marks					**13**

Strength of Materials	Prinicipal Stresses and Strains	1	0	1	1
	Stress and Strain	1	1	2	3
	Torsion of Shafts	0	1	1	2
	Bending Stress	1	0	1	1
	Deflection of Beam	0	1	1	2
Total Marks					**9**
Theory of Machines	Planar Mechanism	1	0	1	1
	Vibration	1	1	2	3
	Balancing	0	1	1	2
Total Marks					**6**
Machine Design	Bolted Joints	0	1	1	2
	Bearings	1	0	1	1
Total Marks					**3**
Thermodynamics	Properties of Pure Substances	1	0	1	1
	SFEE	0	1	1	2
	RAC	0	2	2	4
	Compressors	0	1	1	2
Total Marks					**9**
Fluid Mechanics & Machinary	Flow Through Pipe	1	0	1	1
	Fluid Kinematics	1	1	2	3
	Hydaulic Turbine	1	0	1	1
	Viscous Flow	0	1	1	2
	Impact of Jets	0	1	1	2
Total Marks					**9**
Manufacturing Technology	Non-traditional Machining	1	0	1	1
	Metal Cutting	1	3	4	7
	CIM	1	1	2	3
	Welding	0	1	1	2
	Metrology	0	1	1	2
Total Marks					**15**
Industrial Engineering	Forecasting	0	1	1	2
	Linear Programming	0	1	1	2
	PERT/CPM	1	0	1	1
Total Marks					**5**
Heat and Mass Transfer	Conduction	2	0	2	2
	Convection	1	0	1	1
	Heat Exchangers	1	0	1	1
	Radiation	0	1	1	2
	Transient Conduction	0	1	1	2
Total Marks					**8**
Engineering Mechanics	FBD and Equilibrium	1	1	2	3
	Relative Velocity	1	0	1	1
	Kinematics of Bodies	0	2	2	4
Total Marks					**8**

GATE 2016 Solved Paper
ME: Mechanical Engineering
Set – 1

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

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

A person moving through a tuberculosis-prone zone has a 50% probability of becoming infected. However, only 30% of infected people develop the disease. What percentage of people moving through a tuberculosis-prone zone remains infected but does not show symptoms of the disease?

(A) 15 (B) 33
(C) 35 (D) 37

Solution: We can assume that 50% of the people moving through the zone get infected for a large population. As 30% of these actually develop the disease, the other 70% (i.e., 70% of 50% which is 50% of 70% or 35%) do not develop the disease or do not show symptoms of the disease.

Hence, the correct option is (C).

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

In a world filled with uncertainty, he was glad to have many good friends. He had always assisted them in times of need and was confident that they would reciprocate. However, the events of the last week proved him wrong.

Which of the following inference(s) is/are logically valid and can be inferred from the above passage?

(i) His friends were always asking him to help them.
(ii) He felt that when in need of help, his friends would let him down.
(iii) He was sure that his friends would help him when in need.
(iv) His friends did not help him last week.

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

Solution: Options (iii) and (iv) can be logically inferred from the given text.

Hence, the correct option is (B).

Question Number: 3 **Question Type: MCQ**

Leela is older than her cousin Pavithra. Pavithra's brother Shiva is older than Leela. When Pavithra and Shiva are visiting Leela, all three like to play chess. Pavithra wins more often than Leela does.

Which one of the following statements must be **TRUE** based on the above?

(A) When Shiva plays chess with Leela and Pavithra, he often loses.
(B) Leela is the oldest of the three.
(C) Shiva is a better chess player than Pavithra.
(D) Pavithra is the youngest of the three.

Solution: Shiva > Leela > Pavithra

Statement (B) can be immediately removed as it is wrong.

Statement (D) is TRUE.

Statements (A) and (C), we cannot be certain

Hence, the correct option is (D).

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

If $q^{-a} = \dfrac{1}{r}$ and $r^{-b} = \dfrac{1}{s}$ and $s^{-c} = \dfrac{1}{q}$, the value of abc is __________.

(A) $(rqs)^{-1}$ (B) 0
(C) 1 (D) $r + q + s$

Solution:

$$q^{-a} = r^{-1} \Rightarrow q^a = r \quad (1)$$

$$r^{-b} = s^{-1} \Rightarrow r^b = s \quad (2)$$

$$s^{-c} = q^{-1} \Rightarrow s^c = q \quad (3)$$

Substituting the value of q from Eq. (3) in Eq. (1), we get $s^{ca} = r$. Substituting the value of s from Eq. (2) in this, we get $r^{abc} = r$. Therefore,

$$r = -1, 0, 1 \text{ or } abc = 1$$

None of p, q, r, s is 0. But they could all be –1 (a, b, c would have to be odd numbers, say for example (–1, –3, –5)). We see that their values satisfy the equations.

$$q^{-a} = (-1)^1 = -1 = \frac{1}{r};$$

$$r^{-b} = (-1)^3 = -1 = \frac{1}{s}$$

$$s^{-c} = (-1)^5 = -1 = \frac{1}{q}$$

In this case, abc is –15. Similarly, it can have infinitely many values. If the additional data (that none of q, r, s is –1 or 1) is given, we would be able to conclude that $abc = 1$.

In the exam, in the absence of the correct option, we can guess that the expected answer is choice C.

Hence, the correct option is (C).

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

P, Q, R and S are working on a project. Q can finish the task in 25 days, working alone for 12 hours a day. R can finish the task in 50 days, working alone for 12 hours per day. Q worked 12 hours a day but took sick leave in the beginning for two days. R worked 18 hours a day on all days. What is the ratio of work done by Q and R after 7 days from the start of the project?

(A) 10 : 11 (B) 11 : 10
(C) 20 : 21 (D) 21 : 20

Consider the table given below:

	Q	***R***
Rate	2	1
No of days	5	7
No of hours/day	12	18

The ratio of the work done by Q and R is

$$W_Q/W_R = \frac{2(5)(12)}{1(7)(18)} = \frac{20}{21}.$$

Hence, the correct option is (C).

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

Which of the following is **CORRECT** with respect to grammar and usage?

Mount Everest is __________.

(A) the highest peak in the world
(B) the highest peak in the world
(C) one of highest peak in the world
(D) one of the highest peak in the world

Solution: The superlative adjective ‘highest’ should always be preceded by the definite article ‘the’.

Hence, the correct option is (A).

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

The policeman asked the victim of a theft, ‘What did you __________?’

(A) loose (B) lose
(C) loss (D) louse

Solution: Loss, which is a noun, does not make sense here. Lose means to have something taken away, which is appropriate in the blank. Loose means not firmly fixed. Louse refers to a small insect that lives in the bodies of human and animals.

Hence, the correct option is (B).

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

Despite the new medicine’s __________ in treating diabetes, it is not __________ widely.

(A) effectiveness --- prescribed
(B) availability --- used
(C) prescription --- available
(D) acceptance --- proscribed

Solution: Prescribe means to be told by a doctor to take a particular medicine or have a particular treatment. Proscribe is to ban. The words given in option (A) are precise in the given blanks.

Hence, the correct option is (A).

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

In a huge pile of apples and oranges, both ripe and unripe mixed together, 15% are unripe fruits. Of the unripe fruits, 45% are apples. Of the ripe ones, 66% are oranges. If the pile contains a total of 56,92,000 fruits, how many of them are apples?

(A) 20,29,198 (B) 24,67,482
(C) 27,89,080 (D) 35,77,422

Solution: Consider the table given below:

	Apples	**Oranges**	**Total (%)**	**Total**
Unripe	(0.45)15% = 6.75%		15	
Ripe	(0.34)85% = 28.9%	(0.66)	85	
			100	56,92,000

Among the ripe fruits, 66% are oranges. ∴ 34% are apples.

The percentage of apples in the total number of apples and oranges is

= (0.45) (15) + (0.34) (85) = 6.75 + 28.90 = 35.65.

$$\therefore \text{The number of apples} = \frac{35.65}{100}(56,92,000) = 20,29,198$$

Hence, the correct option is (A).

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

Michael lives 10 km away from where I live. Ahmed lives 5 km away and Susan lives 7 km away from where I live.

Arun is farther away than Ahmed but closer than Susan from where I live. From the information provided here, what is one possible distance (in km) at which I live from Arun's place?

(A) 3.00 (B) 4.99
(C) 6.02 (D) 7.01

Solution:

Ahmed – 5

Arun –

Susan – 7

Michael – 10

The distance at which Arun lives could be x where $5 < x < 7$.

Among the options, it can only be C.

Hence, the correct option is (C).

Mechanical Engineering

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

Q.11 to Q.25 carry 1 mark each and Q.36 to Q.65 carry 2 marks each.

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

The solution to the system of equations $\begin{bmatrix} 2 & 5 \\ -4 & 3 \end{bmatrix}\begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} 2 \\ -30 \end{Bmatrix}$ is

(A) 6, 2 (B) –6, 2
(C) –6, –2 (D) 6, –2

Solution: The system of equations given is

$$\begin{bmatrix} 2 & 5 \\ -4 & 3 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 2 \\ -30 \end{bmatrix}$$

$$\Rightarrow \quad 2x + 5y = 2 \quad (1)$$

$$-4x + 3y = -30 \quad (2)$$

$$2\,(1) + (2) \Rightarrow$$

$$4x + 10y = 4$$

$$-4x + 3y = -30$$

$$\Rightarrow \quad 13y = -26$$

$$y = -26/13$$

$$\Rightarrow \quad y = -2$$

Substituting value of y in Eq. (1), we get

$$2x + 5\,(-2) = 2$$

$$\Rightarrow \quad x = 6$$

The solution to the given system of equations is $x = 6$ and $y = -2$

Hence, the correct option is (D).

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

If $f(t)$ is a function defined for all $t \geq 0$, its Laplace transform $F(s)$ is defined as

(A) $\int_0^\infty e^{st} f(t)\,dt$ (B) $\int_0^\infty e^{-st} f(t)\,dt$

(C) $\int_0^\infty e^{ist} f(t)\,dt$ (D) $\int_0^\infty e^{-ist} f(t)\,dt$

Solution: If $f(t)$ is a function defined for all $t \geq 0$, its Laplace transform $F(s)$ is

$$\int_0^\infty e^{-st} f(t)\,dt$$

Hence, the correct option is (B).

Question Number: 13 **Question Type: MCQ**

$f(z) = u(x, y) + iv(x, y)$ is an analytic function of complex variable $z = x + iy$

where $i = \sqrt{-1}$. If $u(x, y) = 2xy$, then $v(x, y)$ may be expressed as

(A) $-x^2 + y^2$ + constant (B) $x^2 - y^2$ + constant
(C) $x^2 + y^2$ + constant (D) $-(x^2 + y^2)$ + constant

Solution: $f(z) = u(x, y) + iv(x, y)$ is given to be analytic.

Also $u(x, y) = 2xy$

$$\Rightarrow \frac{\partial u}{\partial x} = 2y \text{ and } \frac{\partial u}{\partial y} = 2x \quad (1)$$

As $f(z)$ is analytic, $u(x, y)$ and $v(x, y)$ satisfy Cauchy–Riemann equations.

$$\therefore \frac{\partial u}{\partial x} = \frac{\partial v}{\partial y} \text{ and } \frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x} \quad (2)$$

We know that the exact differential of $v(x, y)$ is

$$dv = \frac{\partial v}{\partial x}dx + \frac{\partial v}{\partial y}dy$$

$$= -\frac{\partial u}{\partial y}dx + \frac{\partial u}{\partial x}dy \quad \text{(from Eq. (2))}$$

$$\therefore \quad \delta v = -2xdx + 2ydy \quad \text{(from Eq. (1))}$$

Integrating on both sides the above equation, we get

$$\int dv = -\int 2x\,dx + \int 2y\,dy$$

$\Rightarrow v = -x^2 + y^2$ + constant

$\therefore v(x, y) = -x^2 + y^2$ + constant

Hence, the correct option is (A).

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

Consider a Poisson distribution for the tossing of a biassed coin. The mean for this distribution is μ. The standard deviation of this distribution is given by

(A) $\sqrt{\mu}$ (B) μ^2
(C) μ (D) $1/\mu$

Solution: We know that the tossing of a biassed coin follows Poisson distribution.

$$\text{mean} = \lambda = \mu$$

Therefore, the variance = $\lambda = \mu$

Standard deviation = $\sqrt{\lambda} = \sqrt{\mu}$

Hence, the correct option is (A).

Question Number: 15 **Question Type: NAT**

Solve the equation $x = 10\cos(x)$ using the Newton–Raphson method. The initial guess is $x = \pi/4$. The value of the predicted root after the first iteration, up to second decimal, is __________.

Solution: The equation is

$$x = 10 \cos x$$

Let $f(x) = x - 10 \cos x$

The derivative of $f(x)$ will be

$\Rightarrow$ $f'(x) = 1 + 10 \sin x$

Given that the initial guess value of x is $x_0 = \dfrac{\pi}{4}$

$\therefore$ $f(x_0) = f\left(\dfrac{\pi}{4}\right) = -6.2857$

and $f'(x_0) = f'\left(\dfrac{\pi}{4}\right) = 8.0711$

$\therefore$ By Newton–Raphson method,

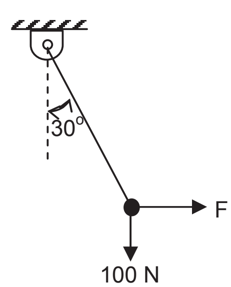
$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} = \frac{\pi}{4} - \frac{(-6.2857)}{(8.0711)}$$

$\therefore$ $x_1 = 1.5642$

Hence, the correct answer is 1.56.

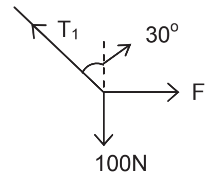
Question Number: 16 **Question Type: NAT**

A rigid ball of weight 100 N is suspended with the help of a string. The ball is pulled by a horizontal force F such that the string makes an angle of 30° with the vertical. The magnitude of force F (in N) is __________.



Solution: Consider the free-body diagram given below:

Weight of rigid ball =100 N



Angle that string makes with vertical = 30°

From the free-body diagram, we get

$$T \cos 30 = 100$$

$$T = 115.47$$

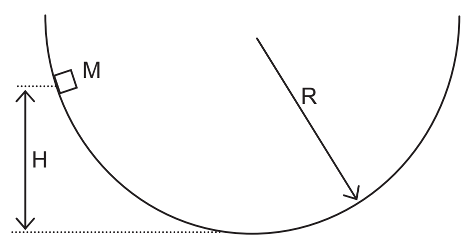
$$T \sin 30 = F$$

$$F = 57.73$$

Hence, the correct answer is 57.5 – 58.0.

Question Number: 17 **Question Type: MCQ**

A point mass M is released from rest and slides down a spherical bowl (of radius R) from a height H as shown in the figure below. The surface of the bowl is smooth (no friction). The velocity of the mass at the bottom of the bowl is



(A) $\sqrt{gH}$ (B) $\sqrt{2gR}$
(C) $\sqrt{2gH}$ (D) 0

Solution: At the bottom of the bowl

Potential energy = Kinetic energy

$$MgH = \frac{1}{2}Mv^2$$

$$v^2 = 2gH$$

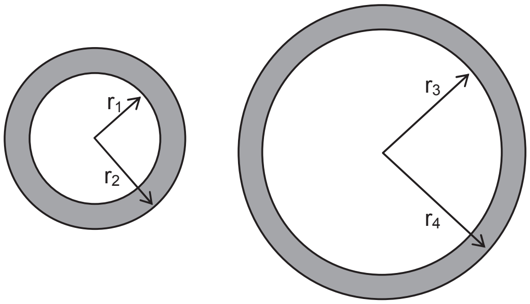
or, $$v = \sqrt{2gH}$$

Hence, the correct option is (C).

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

The cross-sections of two hollow bars made of the same material are concentric circles as shown in the figure. It is given that $r_3 > r_1$ and $r_4 > r_2$, and that the areas of the cross-sections are the same. J_1 and J_2 are the torsional rigidities of the bars on the left and right, respectively. The ratio J_2/J_1 is

(A) > 1 (B) < 0.5
(C) = 1 (D) between 0.5 and 1



Solution: We are given that $r_4 > r_2$; $r_3 > r_1$

Also $$\left(r_4^2 - r_3^2\right) = \left(r_2^2 - r_1^2\right)$$

$$\frac{J_2}{J_1} = \frac{r_4^4 - r_3^4}{r_2^4 - r_1^4} = \frac{r_4^2 + r_3^2}{r_2^2 + r_1^2} \times \frac{r_4^2 - r_3^2}{r_2^2 - r_1^2}$$

$$= \frac{\left(r_2 + x\right)^2 + \left(r_1 + y\right)^2}{r_2^2 + r_1^2} \quad (r_4 = r_2 + x, r_3 = r_1 + y)$$

$$\therefore \quad \frac{J_2}{J_1} > 1$$

Hence, the correct option is (A).

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

A cantilever beam having square cross-section of side *a* is subjected to an end load. If *a* is increased by 19%, the tip deflection decreases approximately by

(A) 19% (B) 29%
(C) 41% (D) 50%

Solution: Deflection can be calculated using

$$y = \frac{Wl^3}{3EI} \quad (1)$$

where

$$I = \frac{bd^3}{12} = \frac{a^4}{12} \quad (b = d = a) \quad (2)$$

Substituting Eq. (2) in Eq. (1), we get

$$\therefore \quad y = \frac{12Wl^3}{3E\left(a\right)^4}$$

When *a* is increased by 19%, then we get the new *a* as a^1 = 1.19 *a*

$$(a^1)^4 = 2a^4$$

Thus,

$$y^1 = \frac{12Wl^2}{3E\left(2a^4\right)} = \frac{y}{2}$$

Hence, the correct option is (D).

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

A car is moving on a curved horizontal road of radius 100 m with a speed of 20 m/s. The rotating masses of the engine have an angular speed of 100 rad/s in the clockwise direction when viewed from the front of the car. The combined moment of inertia of the rotating masses is 10 kg-m^2. The magnitude of the gyroscopic moment (in N-m) is ________.

Solution: Radius of curved road R = 100 m

Speed of car v = 20 m/s

Angular speed ω = 100 rad/s

Combined moment of inertia of the rotating masses I = 10 kg-m^2

$$\omega_P = v/R = \frac{20}{100} = 0.2 \text{ rad/s}$$

The magnitude of the gyroscopic moment will be

$$T_C = I\,\omega\,\omega_P = 10 \times 100 \times 0.2 = 200 \text{ N-m}$$

Hence, the correct answer is 200.

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

A single degree of freedom spring mass system with viscous damping has a spring constant of 10 kN/m. The system is excited by a sinusoidal force of amplitude 100 N. If the damping factor (ratio) is 0.25, the amplitude of steady-state oscillation at resonance is ________ mm.

Solution: Spring constant K = 10 kN/m

Amplitude of force F_0 = 100 N

Damping factor (ratio) is 0.25

The amplitude of steady-state oscillation can be calculated using

$$X_0 = \frac{F_0/K}{\sqrt{\left(1 - \left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

At resonance, $\omega = \omega_n$. Therefore, the above relation becomes

$$X_0 = \frac{100/10^4}{2 \times 0.25}$$

$$= 0.02 \text{ m} = 20 \text{ mm}$$

Hence, the correct answer is 20.

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

The spring constant of a helical compression spring DOES NOT depend on

(A) coil diameter (B) material strength
(C) number of active turns (D) wire diameter

Solution: Spring constant k of a helical compression spring does not depend on material strength.

Hence, the correct option is (B).

Question Number: 23 **Question Type: MCQ**

The instantaneous stream-wise velocity of a turbulent flow is given as follows:

$$u(x, y, z, t) = \bar{u}(x, y, z) + u'(x, y, z, t)$$

The time-average of the fluctuating velocity u'(x, y, z, t) is

(A) $u'/2$ (B) $-\bar{u}/2$
(C) zero (D) $\bar{u}/2$

Solution: Time-average is always zero for fluctuating velocity.

Hence, the correct option is (C).

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

For a floating body, buoyant force acts at the

(A) centroid of the floating body
(B) center of gravity of the body
(C) centroid of the fluid vertically below the body
(D) centroid of the displaced fluid

Solution: Buoyant force acts at the center of buoyance for a floating body, which is the centroid of liquid displaced.

Hence, the correct option is (D).

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

A plastic sleeve of outer radius r_0 = 1 mm covers a wire (radius r = 0.5 mm) carrying electric current. Thermal conductivity of the plastic is 0.15 W/m-K. The heat transfer coefficient on the outer surface of the sleeve exposed to air is 25 W/m^2-K. Due to the addition of the plastic cover, the heat transfer from the wire to the ambient will

(A) increase (B) remain the same
(C) decrease (D) be zero

Solution: Outer radius r_0 = 1 mm

Radius of wire r = 0.5 mm

Thermal conductivity of the plastic k = 0.15 W/m-K

Heat transfer coefficient h_0 = 25 W/m^2-K

$$r_{cr} = \frac{k}{h_0} = \frac{0.5}{25} \times 1000 = 6\ mm$$

Since $r_0 < r_{cr}$

Thus, heat transfer will increase due to the addition of plastic cover.

Hence, the correct option is (A).

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

Which of the following statements are TRUE with respect to heat and work?

(i) They are boundary phenomena
(ii) They are exact differentials
(iii) They are path functions

(A) both (i) and (ii) (B) both (i) and (iii)
(C) both (ii) and (iii) (D) only (iii)

Solution: We know that work and heat are path function, boundary phenomena, and inexact differential.

Hence, the correct option is (B).

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

Propane (C_3H_8) is burned in an oxygen atmosphere with 10% deficit oxygen with respect to the stoichiometric requirement. Assuming no hydrocarbons in the products, the volume percentage of CO in the products is __________.

Solution: The following reaction will take place when propane (C_3H_8) is burned in an oxygen atmosphere with 10% deficit oxygen with respect to the stoichiometric requirement:

$$C_3H_8 + 4.5\,O_2 \rightarrow CO + 2\,CO_2 + 4\,H_2O$$

$$\text{Volume \% of CO in products} = \frac{1}{7} \times 100 = 14.28\%$$

Hence, the correct answer is 14.2 to 14.3.

Question Number: 28 **Question Type: NAT**

Consider two hydraulic turbines having identical specific speed and effective head at the inlet. If the speed ratio (N_1/N_2) of the two turbines is 2, then the respectively power ratio (P_1/P_2) is __________.

Solution: We know that

$$N_S = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_S H^{5/4} = N\sqrt{P}$$

We are given that $N_{S1} = N_{S2}$, $H_1 = H_2$

$$\therefore \quad \left(N\sqrt{P}\right)_1 = \left(N\sqrt{P}\right)_2$$

$$\frac{N_1}{N_2} = \sqrt{\frac{P_2}{P_1}}$$

$$\frac{P_1}{P_2} = \left(\frac{N_2}{N_1}\right)^2 = \left(\frac{1}{2}\right)^2 = 0.25$$

Hence, the correct answer is 0.25.

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

The INCORRECT statement about regeneration in vapor power cycle is that

(A) it increases the irreversibility by adding the liquid with higher energy content to the steam generator
(B) heat is exchanged between the expanding fluid in the turbine and the compressed fluid before heat addition

(C) the principle is similar to the principle of Stirling gas cycle
(D) it is practically implemented by providing feed water heaters

Solution: We know that adiabatic mixing of two fluids is always irreversible and two fluids are mixed in the regenerative heat exchanger. So, it increases the irreversibility.

Hence, the correct option is (A).

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

The 'Jominy test' is used to find
(A) Young's modulus (B) hardenability
(C) yield strength (D) thermal conductivity

Solution: The correct option is (B).

Question Number: 31 **Question Type: MCQ**

Under optimal conditions of the process, the temperatures experienced by a copper work piece in fusion welding, brazing, and soldering are such that
(A) $T_{\text{welding}} > T_{\text{soldering}} > T_{\text{brazing}}$
(B) $T_{\text{soldering}} > T_{\text{welding}} > T_{\text{brazing}}$
(C) $T_{\text{brazing}} > T_{\text{welding}} > T_{\text{soldering}}$
(D) $T_{\text{welding}} > T_{\text{brazing}} > T_{\text{soldering}}$

Solution: $T_{\text{welding}} > T_{\text{Brazing}} > T_{\text{welding}}$.
Hence, the correct option is (D).

Question Number: 32 **Question Type: MCQ**

The part of a gating system which regulates the rate of pouring of molten metal is
(A) pouring basin (B) runner
(C) choke (D) ingate

Solution: We know that the rate of pouring of molten metal is regulated by choke.

Hence, the correct option is (C).

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

The non-traditional machining process that essentially required vacuum is
(A) electron beam machining
(B) electrochemical machining
(C) electrochemical discharge machining
(D) electro discharge machining

Solution: We know that vacuum is required by electron beam machining.

Hence, the correct option is (A).

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

In an orthogonal cutting process, the tool used has rake angle of zero degree. The measured cutting force and thrust force are 500 N and 250 N, respectively. The coefficient of friction between the tool and the chip is ________.

Solution: Thrust force F_t= 250 N
Cutting force F_c= 500 N
We know that

$$\tan(\beta - \alpha) = \frac{F_t}{F_c}$$

$$\alpha = 0$$

$$\therefore \quad \tan\beta = \frac{F_t}{F_c} = \frac{250}{500} = 0.5$$

The coefficient of friction between the tool and the chip is

$$\mu = \tan\beta = 0.5.$$

Hence, the correct answer is 0.5.

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

Match the following

P. Feeler gauge	I. Radius of an object
Q. Fillet gauge	II. Diameter within limits by comparison
R. Snap gauge	III. Clearance or gap between components
S. Cylindrical plug gauge	IV. Inside diameter of straight hole

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

Solution: The correct mapping is

P.	Feeler gauge	III.	Clearance between components
Q.	Fillet gauge	I.	Radius of an object
R.	Snap gauge	II.	Diameter within limits by comparison
S.	Cylindrical plug	IV.	Inside diameter of gauge straight hole

Hence, the correct option is (A).

Q.26 to Q.55 carry two marks each.

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

26. Consider the function $f(x) = 2x^3 - 3x^2$ in the domain [–1, 2]. The global minimum of $f(x)$ is ________.

Solution: Given $f(x) = 2x^3 - 3x^2$ in the domain [–1, 2].

$$f'(x) = 6x^2 - 6x$$

$$f'(x) = 0 \Rightarrow 6x^2 - 6x = 0 \Rightarrow x^2 - x = 0$$

$$\Rightarrow \quad \xi\,(x - 1) = 0$$

$$\Rightarrow \quad \xi = 0, x = 1$$

$\therefore$ The stationary values of $f(x)$ are $x = 0$ and $x = 1$.

$\therefore$ The global minimum of $f(x)$ in [–1, 2]

= Min {$f(-1), f(0), f(1), f(2)$}

= Min {–5, 0, –1, 4} = –5

Hence, the correct answer is –5.

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

If $y = f(x)$ satisfies the boundary value problem $y'' + 9y = 0$, $y(0) = 0$, $y(\pi/2) = \sqrt{2}$, then $y(\pi/4)$ is ________.

Solution: Given boundary value problem is

$$y'' + 9y = 0 \quad (1)$$

where $y(0) = 0$ and $y\left(\frac{\pi}{2}\right) = \sqrt{2}y$ (2)

The auxiliary equation of (1) is

$$D^2 + 9 = 0 \Rightarrow D = \pm 3i$$

∴ The general solution of (1) is

$$y = c_1 \cos 3x + c_2 \sin 3x \quad (3)$$

Given $y(0) = 0$

$\Rightarrow$ $0 = c_1 \cos(3 \times 0) + c_2 \sin(3 \times 0)$

$\Rightarrow$ $\chi_1 = 0$

Also, given $y\left(\frac{\pi}{2}\right) = \sqrt{2}$

∴ From Eq. (3),

$$\sqrt{2} = c_1 \cos\left(3\times\frac{\pi}{2}\right) + c_2 \sin\left(3\times\frac{\pi}{2}\right)$$

$$\Rightarrow \sqrt{2} = c_1 \times 0 + c_2 \times (-1)$$

$$\Rightarrow c_2 = -\sqrt{2}$$

Substituting the values of c_1 and c_2 in Eq. (3), we get

$$y = -\sqrt{2}\sin 3x$$

$$\therefore \quad y\left(\frac{\pi}{4}\right) = -\sqrt{2}\sin\left(3\times\frac{\pi}{4}\right)$$

$$= -\sqrt{2}\sin\left(\frac{3\pi}{4}\right) = -\sqrt{2}\times\frac{1}{\sqrt{2}}$$

$$\therefore \quad y\left(\frac{\pi}{4}\right) = -1$$

Hence, the correct answer is –1.

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

The value of the integral $\int_{-\infty}^{\infty} \frac{\sin x}{x^2+2x+2}dx$ evaluated using contour integration and the residue theorem is

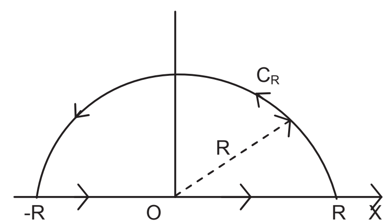
(A) $-\pi \sin(1)/e$ (B) $-\pi \cos(1)/e$

(C) $\sin(1)/e$ (D) $\cos(1)/e$

Solution: We have to evaluate $\int_{-\infty}^{\infty} \frac{\sin x}{x^2+2x+2}dx$

Let $$f(z) = \frac{e^{iz}}{z^2+2z+2}$$

Consider the contour integral $\oint_C f(z)\,dz$



where C is the contour consisting of the semi-circle C_R : $|z| = R$, together with the diameter that closes it.

The singularities of $f(z) = \frac{e^{iz}}{z^2+2z+2}$ are

$$-1 + i \text{ and } -1 - i$$

Let $z_1 = -1 + i$ and $z_2 = 1 - i$

Clearly z_1 lies inside the semi-circle but z_2 does not lie.

∴ By Cauchy's residue theorem, we have

$$\oint_C f(z)\,dz = 2\pi i\left(\operatorname{Res}_{z=z_1}(f(z))\right) \quad (1)$$

$$\operatorname{Res}_{z=z_1}(f(z)) = \operatorname{Lt}_{z\to z_1}[(z-z_1)f(z)]$$

$$\operatorname{Lt}_{z\to z_1}\left[(z-z_1)\frac{e^{iz}}{z^2+2z+2}\right]$$

$$\therefore \quad \operatorname{Res}_{z=z_1}[f(z)] = \frac{e^{-1-i}}{2i}$$

∴ From Eq. (1), we have

$$\oint_C f(z)\,dz = \int_{C_R} f(z)\,dz + \int_{-R}^{R} f(x)\,dx = 2\pi i\times\frac{e^{-1-i}}{2i}$$

As $R\to\infty$, we have

$$\int_{-\infty}^{\infty} f(x)\,dx = \pi(e^{-1-i})$$

$$\Rightarrow \int_{-\infty}^{\infty} \frac{e^{ix}}{x^2+2x+2}dx = \pi\left[e^{-1}\,(e^{-i})\right]$$

$$\Rightarrow \int_{-\infty}^{\infty} \frac{\cos x + i\sin x}{x^2+2x+2}dx = \frac{\pi}{e}[\cos 1 - i\sin 1]$$

$$\Rightarrow \int_{-\infty}^{\infty} \frac{\cos x}{x^2+2x+2}dx + i\int_{-\infty}^{\infty} \frac{\sin x}{x^2+2x+2}dx$$

$$= \frac{\pi}{e}[\cos 1 - i\sin 1]$$

Comparing the imaginary parts on both sides,

$$\int_{-\infty}^{\infty} \frac{\sin x}{x^2+2x+2}dx = -\frac{\pi}{e}\sin(1)$$

Hence, the correct option is (A).

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

Gauss–Seidel method is used to solve the following equations (as per the given order):

$$x_1 + 2x_2 + 3x_3 = 5$$
$$2x_1 + 3x_2 + x_3 = 1$$
$$3x_1 + 2x_2 + x_3 = 3$$

Assuming initial guess as $x_1 = x_2 = x_3 = 0$, the value of x_3 after the first iteration is ________.

Solution: Given system of equations is

$$x_1 + 2x_2 + 3x_3 = 5$$
$$2x_1 + 3x_2 + x_3 = 1$$
$$3x_1 + 2x_2 + x_3 = 3$$

As the Gauss–Seidal method is used to solve the above equations as per the given order, we have to solve the first equation for x_1, the second equation for x_2, and the third equation for x_3.

$\therefore$ $$x_1 = 5 - 2x_2 - 3x_3 \quad (1)$$

$$x_2 = x_2 = \frac{1}{3} - \frac{2}{3}x_1 - \frac{x_3}{3} \quad (2)$$

and $$x_3 = 3 - 3x_1 - 2x_2 \quad (3)$$

Given the initial guess values are $x_1 = x_2 = x_3 = 0$

i.e., $x_1^{(0)} = 0,\ x_2^{(0)} = 0$ and $x_3^{(0)} = 0$

$\therefore$ From Eq. (1), we have

$$x_1^{(1)} = 5 - 2x_2^{(0)} - 3x_3^{(0)}$$
$$= 5 - 2 \times 0 - 3 \times 0$$
$$\therefore\ x_1^{(1)} = 5$$

From Eq. (2), we have

$$x_2^{(1)} = \frac{1}{3} - \frac{2}{3}x_1^{(1)} - \frac{1}{3}x_3^{(0)} = \frac{1}{3} - \frac{2}{3}\times 5 - \frac{1}{3}\times 0$$

$$\therefore\ x_2^{(1)} = -3$$

From Eq. (3), we have

$$x_3^{(1)} = 3 - 3x_1^{(1)} - 2x_2^{(1)}$$
$$= 3 - 3\times 5 - 2\times(-3)$$
$$= 3 - 15 + 6$$
$$\therefore\ x_3^{(1)} = -6$$

Hence, the value of x_3 after the first iteration is $x_3^{(1)} = -6$

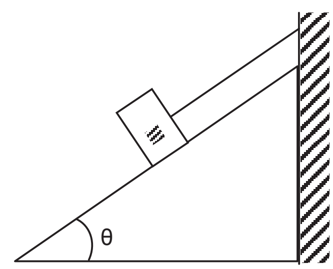
Hence, the correct answer is 6.

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

A block of mass m rests on an inclined plane and is attached by a string to the wall as shown in the figure. The coefficient of static friction between the plane and the block is 0.25. The string can withstand a maximum force of 20 N. The maximum value of the mass (m) for which the string will not break and the block will be in static equilibrium is ________ kg.

Take $\cos\theta = 0.8$ and $\sin\theta = 0.6$

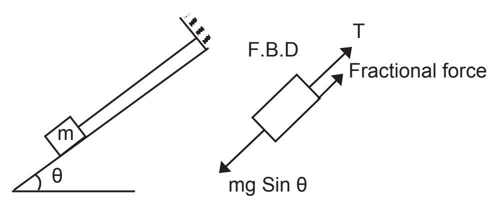
Acceleration due to gravity g = 10 m/s^2



Solution: Coefficient of friction $\mu = 0.25$

Maximum force $T_{max} = 20$ N

$$\cos\theta = 0.8$$
$$\sin\theta = 0.6$$



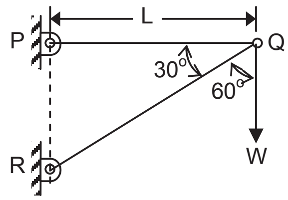
From the above figure, we conclude that

$$T + \mu mg\cos\theta = mg\sin\theta$$
$$20 + 0.25g\,(0.8m) = mg\ 0.6$$
$$20 = mg[0.6 - 0.25 \times 0.8]$$
$$\Rightarrow \quad m = 5 \text{ kg}$$

Hence, the correct answer is 5.

Question Number: 41 **Question Type: MCQ**

A two-member truss PQR is supporting a load W. The axial forces in members PQ and QR are respectively.



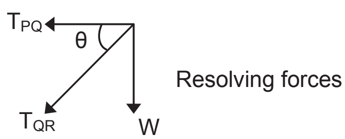
(A) $2W$ tensile and $\sqrt{2}W$ compressive

(B) $\sqrt{3}W$ tensile and $2W$ compressive

(C) $\sqrt{3}W$ compressive and $2W$ tensile

(D) $2W$ compressive and $\sqrt{3}W$ tensile

Solution: In the free-body diagram given below, consider the equilibrium of Pin Joint Q.



For equilibrium, we will have

$$T_{PQ} + T_{QR}\cos\theta = 0$$

$$W + T_{QR}\sin\theta = 0$$

$$T_{QR} = \frac{-W}{\sin\theta} = \frac{-W}{0.5} = -2W$$

(Assume directions are opposite)

Aslo

$$T_{PQ} = -T_{QR}\cos\theta$$

$$= 2W \times \frac{\sqrt{3}}{2} = \sqrt{3}\,W$$

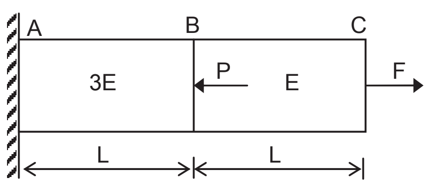
$$\therefore \quad T_{PQ} = \sqrt{3}\,W \text{ tensile}$$

$$T_{QR} = 2W \text{ Compressive.}$$

Hence, the correct option is (B).

Question Number: 42 **Question Type: NAT**

A horizontal bar with a constant cross-section is subjected to loading as shown in the figure. The Young's moduli for the sections AB and BC are $3E$ and E, respectively.



For the deflection at C to be zero, the ratio P/F is ________.

Solution: For equilibrium of forces, we have

$$R_A + P = F \quad (1)$$

$$\delta_C = 0$$

$$\frac{R_A L}{A(3E)} + \frac{(R_A + P)L}{AE} = 0 \quad (2)$$

$$\frac{R_A}{3} + \frac{(R_A + P)}{1} = 0$$

$$4R_A = -3P$$

$$R_A = \frac{-3}{4}P \quad (3)$$

Substituting Eq. (3) in Eq. (1), we get

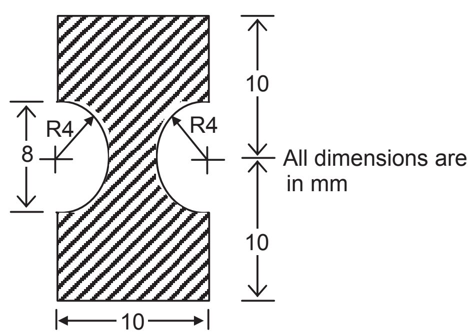
$$\frac{1}{4}P = F$$

$$\frac{P}{F} = 4$$

Hence, the correct answer is 4.

Question Number: 43 **Question Type: NAT**

The figure shows cross-section of a beam subjected to bending. The area moment of inertia (in mm^4) of this cross-section about its base is ________.



Solution: Using Parallel Axis theorem, we get

$$A_I = \left(\frac{10 \times 10^3}{12} + 10\times10\times5^2\right) - \left[\left(\frac{\pi}{64}\times8^4\right) + \pi\times4^2\times5^2\right]$$

$$= 3333.33 - 1457.69$$

$$= 1875.63 \text{ mm}^4$$

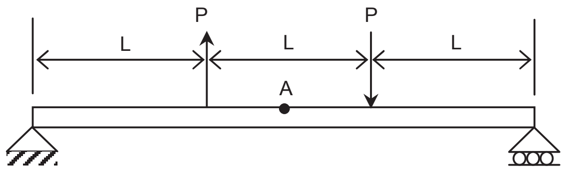
Hence, the correct answer is 1873 to 1879.

Question Number: 44 **Question Type: NAT**

A simply-supported beam of length $3L$ is subjected to the loading shown in the figure.

It is given that $P = 1$ N, $L = 1$ m, and Young's modulus $E = 200$ GPa. The cross-section is a square with dimension

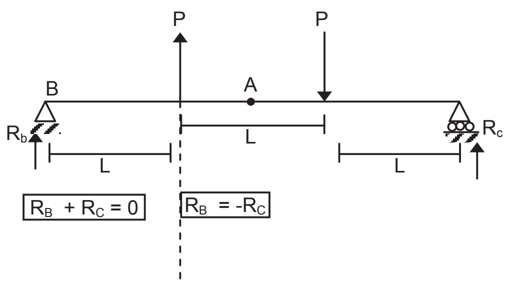
10 mm × 10 mm. The bending stress (in Pa) at the point A located at the top surface of the beam at a distance of $1.5L$ from the left end is __________.



Solution: Young's modulus $E = 200$ GPa

Force $P = 1$ N

Length $L = 1$ m

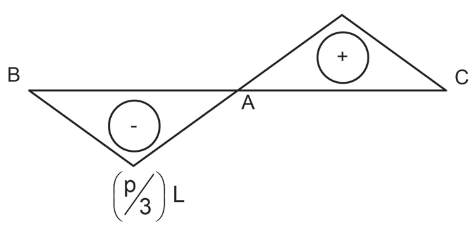


For moment at point B,

$$R_C \times 3L - P \times 2L + P \times L = 0$$

$$R_C = \frac{P}{3}$$

$$R_B = \frac{-P}{3}$$



For moment at $A = -R_B\,(1.5L) + P \times 0.5L$

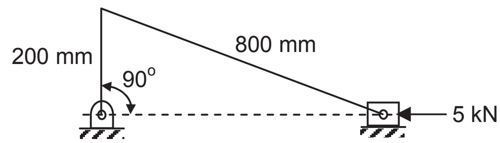
$$= -\frac{P}{3}(1.5L) + P \times 0.5L = 0 \text{ N-m}$$

Therefore, bending stress at point A is zero.

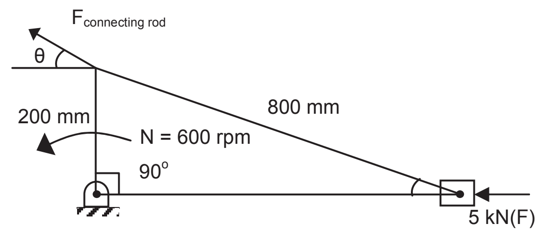
Hence, the correct answer is 0.

Question Number: 45 **Question Type: NAT**

A slider crank mechanism with crank radius 200 mm and connecting rod length 800 mm is shown. The crank is rotating at 600 rpm in the counterclockwise direction. In the configuration shown, the crank makes an angle of 90° with the sliding direction of the slider, and a force of 5 kN is acting on the slider. Neglecting the inertia forces, the turning moment on the crank (in kN-m) is __________.



Solution:



Crank radius $r = 200$ mm

Rod length $L = 800$ mm

Force $F = 5$ KN $= 5 \times 10^3$ N

Turning moment on crank

$$= \frac{F}{\cos\theta}\sin(90+\theta)\,r$$

$$= \frac{F\cos\theta}{\cos\theta}(r)$$

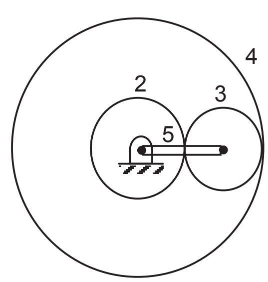
$$= Fr = 5 \times 10^3 \times 0.2$$

$$= 1000 \text{ N-m} \approx 1 \text{ kNm}$$

Hence, the correct answer is 1.

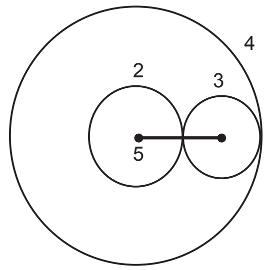
Question Number: 46 **Question Type: NAT**

In the gear train shown, gear 3 is carried on arm 5. Gear 3 meshes with gear 2 and gear 4. The number of teeth on gears 2, 3, and 4 are 60, 20, and 100, respectively. If gear 2 is fixed and gear 4 rotates with an angular velocity of 100 rpm in the counterclockwise direction, the angular speed of arm 5 (in rpm) is



(A) 166.7 counterclockwise
(B) 166.7 clockwise
(C) 62.5 counterclockwise
(D) 62.5 clockwise

Solution:



We know that

N_4 = 100 rpm C.C.W

N_5 = ?

Let the angular speed of gear 2 be x and y be the angular speed of arm. Consider the table given below:

Gear	2	3	4
Teeth	60	20	100
Without arm speed	1	$\frac{-60}{20}$	$\frac{-60}{20}\times\frac{20}{100}$
x rev	x	$-x\left(\frac{60}{20}\right)$	$\frac{(x)\,60}{20}\times\frac{20}{100}$
With arm speed	$y + x$	$y - 3x$	$y-\frac{6x}{10}$

$$y + x = 0 \quad (1)$$

$$y-\frac{3}{5}x=100 \quad (2)$$

From Eqs. (1) and (2), we get

$$y+\frac{3}{5}y=100$$

$$8y = 500$$

$$y = 62.5$$

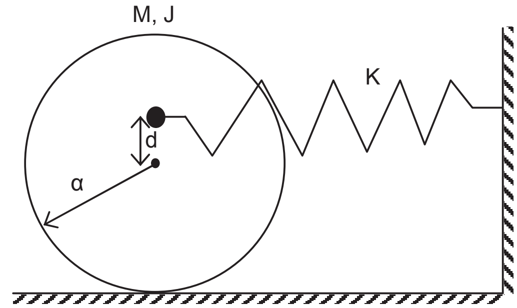
and $$x = -62.5$$

Thus, speed of arm (N_5) = 62.5 C.C.W.

Hence, the correct option is (C).

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

A solid disc with radius a is connected to a spring at a point d above the center of the disc. The other end of the spring is fixed to the vertical wall. The disc is free to roll without slipping on the ground. The mass of the disc is M and the spring constant is K. The polar moment of inertia for the disc about its center is $J = M a^2/2$.

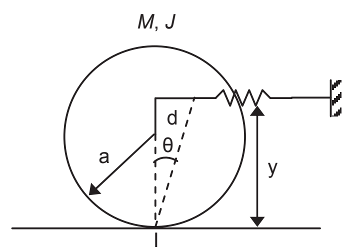


The natural frequency of this system in rad/s is given by

(A) $\sqrt{\frac{2K(a+d)^2}{3Ma^2}}$ (B) $\sqrt{\frac{2K}{3M}}$

(C) $\sqrt{\frac{2K(a+d)^2}{Ma^2}}$ (D) $\sqrt{\frac{K(a+d)^2}{Ma^2}}$

Solution: Consider the figure given below:



If θ be an angular deflection of disc

$$x = r\theta \text{ and } r = a + d$$

Moment of inertia of disc

$$I=\frac{ma^2}{2}+ma^2=\frac{3}{2}ma^2$$

Applying torque equation,

$$I\ddot{\theta}+kxy=0$$

$$\frac{3}{2}ma^2\ddot{\theta}+k(a+d)^2\theta=0$$

$$\omega_n=\sqrt{\frac{2k(a+d)^2}{3ma^2}}$$

Hence, the correct option is (A).

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

The principal stresses at a point inside a solid object are σ_1 = 100 MPa, σ_2 = 100 MPa, and σ_3 = 0 MPa. The yield strength of the material is 200 MPa. The factor of safety calculated using Tresca (maximum shear stress) theory is n_T and the factor of safety calculated using von Mises (maximum distortional energy) theory is n_v. Which one of the following relations is TRUE?

(A) $n_T = \left(\sqrt{3}/2\right) n_V$ (B) $n_T = \left(\sqrt{3}\right) n_V$

(C) $n_T = n_V$ (D) $n_V = \left(\sqrt{3}\right) n_T$

Solution: Principal stresses $\sigma_1 = 100$ MPa

Principal stresses $\sigma_2 = 100$ MPa

Principal stresses $\sigma_3 = 0$

Yield strength $S_{yT} = 200$ MPa

According to Tresca's theory,

$$\sigma_1 \le S_{yT}/N$$

$$100 \le 200/n_T \quad (1)$$

According to Von Mises theory,

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2$$

$$= 2\left(\frac{S_{yT}}{n_V}\right)^2 = 2(\sigma_1)^2 = 2\left(\frac{S_{yT}}{n_V}\right)^2$$

$$= \sigma_1 = \frac{S_{yT}}{n_V} \quad (2)$$

From Eqs. (1) and (2), we get

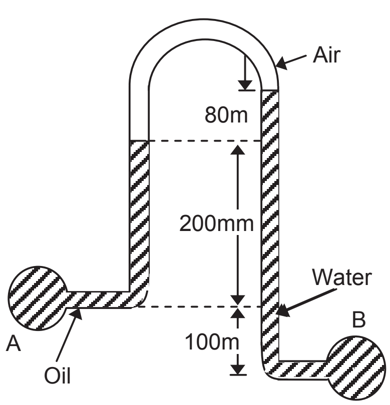
$$n_T = n_V$$

Hence, the correct option is (C).

Question Number: 49 **Question Type: NAT**

An inverted U-tube manometer is used to measure the pressure difference between two pipes *A* and *B*, as shown in the figure. Pipe *A* is carrying oil (specific gravity = 0.8) and pipe *B* is carrying water. The densities of air and water are 1.16 kg/m³, respectively. The pressure difference between pipes *A* and *B* is __________ kPa.

Acceleration due to gravity g = 10 m/s².



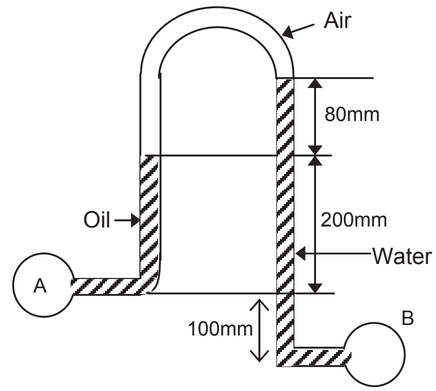
Solution:

Density of oil $\rho_{oil} = 800$ kg/m³

Density of water $\rho_{water} = 1000$ kg/m³

Density of air $\rho_{air} = 1.16$ kg/m³

Acceleration due to gravity $g = 10$ m/s²



$$P_A - \rho_{oil}\, g\,(0.2) - \rho_{air}\, g\,(0.08) + \rho_{water}\, g\,(0.38) = P_B$$

$$\therefore \quad P_B - P_A = 2.199 \text{ kPa}$$

Hence, the correct answer is –2.2 kPa.

Question Number: 50 **Question Type: NAT**

40. Oil (kinematic viscosity, $\upsilon_{oil} = 1.0 \times 10^{-5}$ m²/s) flows through a pipe of 0.5 m diameter with a velocity of 10 m/s. Water (kinematic viscosity, $\upsilon_w = 0.89 \times 10^{-6}$ m²/s) is flowing through a model pipe of diameter 20 mm. For satisfying the dynamic similarity, the velocity of water (in m/s) is __________.

Solution: Kinematic viscosity of oil $\upsilon_{oil} = 1 \times 10^{-5}$ m²/s

Diameter of pipe $d_{oil} = 0.5$ m

Velocity $V_{oil} = 10$ m/s

Kinematic viscosity of water $\upsilon_{water} = 0.89 \times 10^{-6}$ m²/s

Diameter of pipe $d_{water} = 0.02$ m

Equating Reynolds number, we get

$$\frac{V_{oil}\, d_{oil}}{\upsilon_{oil}} = \frac{V_{water}\, d_{water}}{\upsilon_{water}}$$

$$\Rightarrow \frac{0.5 \times 10}{10^{-5}} = \frac{V_{water} \times 0.02}{0.89 \times 10^{-6}}$$

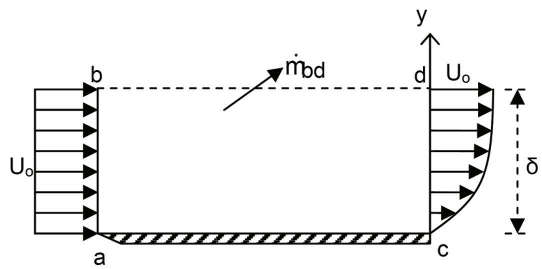
$$V_{water} = 22.25 \text{ m/s}$$

Hence, the correct answer is 22 to 22.5.

Question Number: 51 **Question Type: NAT**

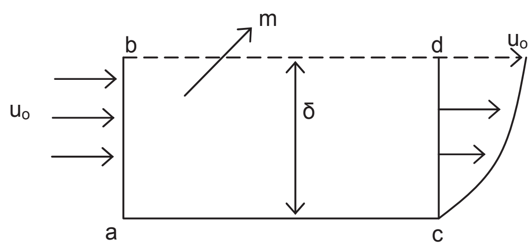
A steady laminar boundary layer is formed over a flat plate as shown in the figure. The free stream velocity of the fluid is U_o. The velocity profile at the inlet *a*-*b* is uniform, while that at the downstream location *c*-*d* given by

$$u = U_o\left[2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right].$$



The ratio of the mass flow rate, $\dot{m}_{bd}$, leaving through the horizontal section *b*-*d* to that entering through the vertical section *a*-*b* is __________.

Solution: From the above figure, we get



$$\dot{m}_{ab} = \rho u_o \delta$$

$$\dot{m}_{cd} = \int_0^\delta \rho u_o\left[2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right]dy$$

$$= \rho u_o\left[\delta - \frac{\delta}{3}\right]$$

$$= \frac{2}{3}\rho u_o \delta$$

$$\therefore \quad \dot{m}_{bd} = \frac{1}{3}\rho u_o \delta,$$

As $$\dot{m}_{ab} = \dot{m}_{cd} + \dot{m}_{bd}$$

$$\therefore \quad \frac{\dot{m}_{bd}}{\dot{m}_{ab}} = \frac{1}{3} \approx 0.333$$

Hence, the correct answer is 0.32 – 0.34.

Question Number: 52 **Question Type: NAT**

42. A steel ball of 10 mm diameter at 1000 K is required to be cooled to 350 K by immersing it in a water environment at 300 K. The convective heat transfer coefficient is 1000 W/m^2-K. Thermal conductivity of steel is 40 W/mK. The time constant for the cooling process τ is 16 s. The time required (in s) to reach the final temperature is __________.

Solution: Diameter of steel ball d = 10 mm

Initial temperature T_0 = 1000 K

Final temperature T_1 = 350 K

Temperature of water T_∞ = 300 K

Convective heat transfer coefficient h = 1000 W/m^2-K

Thermal conductivity of steel k = 40 W/m-K

Time constant τ = 16 s

We know that the time constant can be expressed as

$$\tau = \frac{\rho VC}{hA} = 16\,\text{s}$$

$$\frac{T_0 - T_\infty}{T_1 - T_\infty} = e^{(hA/\rho VC)}t$$

$$\Rightarrow \quad \frac{1000-300}{350-300} = e^{t/16}$$

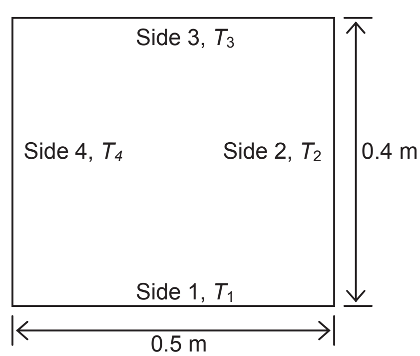
$$t = 42.22 \text{ s}$$

Hence, the correct answer is 42 – 43.

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

An infinitely long furnace of 0.5 m × 0.4 m cross-section is shown in the figure below. Consider all surfaces of the furnace to be black. The top and bottom walls are maintained at temperature $T_1 = T_3 = 927^oC$ while the side walls are at temperature $T_2 = T_4 = 527^oC$. The view factor, F_{12} is 0.26. The net radiation heat loss or gain on side 1 is __________ W/m.

Stefan-Boltzmann constant = 5.67×10^{-8} W/m^2-K^4

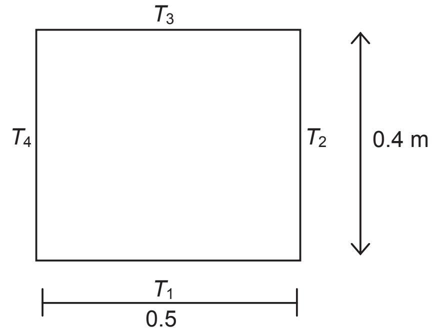


Solution: Temperature $T_1 = T_3$ = 1200 K

Temperature $T_2 = T_4$ = 800 K

View factor F_{12} = 0.26

For symmetry, $F_{12} = F_{14}$ = 0.26



Also

$$F_{13} = 1 - 2F_{12}$$
$$= 1 - 2 \times 0.26$$
$$= 0.48$$

Radiative heat exchange between 1 and 2, and 1 and 4 is same

$$\therefore \quad Q_{12} + Q_{14} = 2F_{12}\, \varepsilon\sigma\left(T_1^4 - T_2^4\right)$$
$$= 2 \times 0.26 \times 5.67 \times 10^{-8}\ [1200^4 - 800^4]$$
$$= 49061.376\ \text{W/m}^2$$
$$Q_{13} = F_{13}\, \varepsilon\sigma\left[T_1^4 - T_3^4\right] = 0$$

$$Q_{\text{NET}} \times 0.5 = 49061.376 \times 0.5\ \text{W/m}$$
$$= 24530.688\ \text{W/m}$$

Hence, the correct answer is 24528 – 24532.

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

A fluid (Prandtl number, $Pr = 1$) at 500 K flows over a flat plate of 1.5 m length, maintained at 300 K. The velocity of the fluid is 10 m/s. Assuming kinematic viscosity, $\upsilon = 30 \times 10^{-6}$ m^2/s, the thermal boundary layer thickness (in mm) at 0.5 m from the leading edge is __________.

Solution: Prandtl number $Pr = 1$

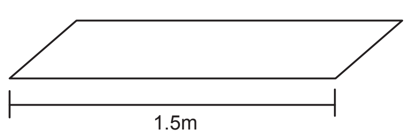
Temperature of fluid $T_\infty = 500$ K;

Temperature of plate $T_w = 300$ K

Velocity $V_\infty = 10$ m/s;

Kinematic viscosity $\upsilon = 30 \times 10^{-6}$ m^2/s

$$\frac{\delta_{\text{th}}}{\delta} = (Pr)^{-1/3}$$



$$R_c = \frac{Vd}{\vartheta} = \frac{10 \times 0.5}{30 \times 10^{-6}} = 0.1667 \times 10^6$$
$$\approx 1.6667 \times 10^5.$$

Therefore, the flow is laminar.

Hydrodynamic boundary layer at 0.5 will be

$$= \frac{5x}{\sqrt{R_{\text{ex}}}} = \frac{5 \times 0.5}{\sqrt{1.6667 \times 10^5}} \approx 6.12 \times 10^{-3}\ \text{m}$$

$$\delta_{th} = 6.12\ \text{mm}$$

Hence, the correct answer is 6 to 6.25

Question Number: 55 **Question Type: NAT**

45. For water at 25°C, $dp_s/dT_s = 0.189$ kPa/K (P_s is the saturation pressure in kPa and T_s is the saturation temperature in K) and the specific volume of dry saturated vapor is 43.38 m^3/kg. Assume that the specific volume of liquid is negligible in comparison with that of vapor. Using the Clausius-Clapeyron equation, an estimate of the enthalpy of evaporation of water at 25°C (in kJ/kg) is __________.

Solution: Temperature of water $T_{\text{sat}} = 25$°C

$$\frac{dP_s}{dT_s} = 0.189\ \text{k Pa/K};$$

Specific volume of dry saturated vapor $\upsilon = 43.38$ m^3/kg

$$\frac{dP_s}{dT_s} = \frac{h_{fg}}{T_{\text{sat}}\, V_g} \quad (\text{Here, } v_g = v_{fg})$$

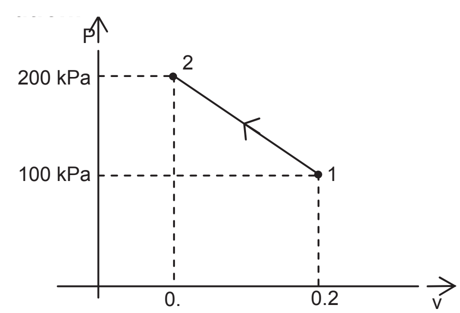
$$0.189 \times 10^3 = \frac{h_{fg}}{298 \times 43.38}$$

$$h_{fg} = 2443.24\ \text{kJ/kg}$$

Hence, the correct answer is 2400 – 2500.

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

An ideal gas undergoes a reversible process in which the pressure varies linearly with volume. The conditions at the start (subscript 1) and at the end (subscript 2) of the process with usual notation are: $p_1 = 100$ kPa, $V_1 = 0.2$ m^3, and $p_2 = 200$ kPa, $V_2 = 0.1$ m^3 and the gas constant, $R = 0.275$ kJ/kg-K. The magnitude of the work required for the process (in kJ) is __________.



Solution: Gas constant $R = 0.275$ kJ/kg-K

Pressure $p_1 = 100$ kPa

Volume $V_1 = 0.2$ m^3

Pressure $p_2 = 200$ kPa

Volume $V_2 = 0.1$ m^3

Work done = area under the curve 1, 2

$$= \frac{1}{2} \times 100 \times 10^3 \times 0.1 + 100 \times 10^3 \times 0.1 = 15{,}000 \text{ J}$$

Hence, the correct answer is 15.

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

In a steam power plant operating on an ideal Rankine cycle, superheated steam enters the turbine at 3 MPa and 350°C. The condenser pressure is 75 kPa. The thermal efficiency of the cycle is ________ percent.

Given data:

For saturated liquid, at $P = 75$ kPa, h_f

= 384.39 kJ/kg, $v_f = 0.001037$ m^3/kg, s_f

= 1.213 kJ/kg-K

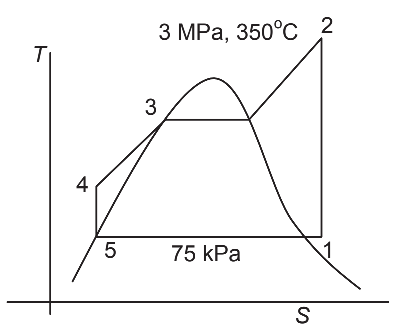
At 75 kPa, $h_{fg} = 2278.6$ kJ/kg,

$s_{fg} = 6.2434$ kJ/kg-K

At P = 3 MPa and T = 350°C (superheated steam), h = 3115.3 kJ/kg,

$s = 6.7428$ kJ/kg-K

Solution:



From the figure we conclude that process 1 – 2 is isentropic process; therefore,

$$S_2 = S_1$$
$$S_2 = S_{f_1} + x\,S_{fg}$$
$$x = 0.886$$
$$h_1 = h_{f_1} + x\,h_{fg_1}$$
$$= 384.39 + 0.886 \times 2278.6$$
$$= 2403.23 \text{ kJ/kg}$$

The thermal efficiency of the cycle is

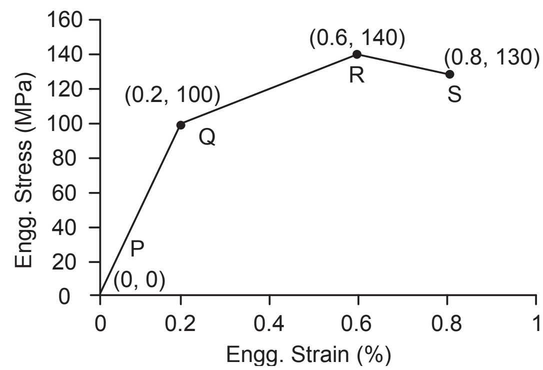
$$\eta = \frac{h_2 - h_1}{h_2 - h_5} = \frac{3115.3 - 2403.23}{3115.3 - 384.39} = 0.2607$$

$$\eta = 26.07\%$$

Hence, the correct answer is 25.8 to 26.

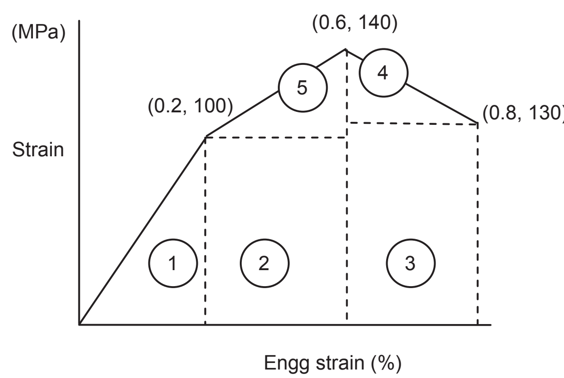
Question Number: 58 **Question Type: MCQ**

A hypothetical engineering stress–strain curve shown in the figure has three straight lines PQ, QR, RS with coordinates P(0, 0), Q(0.2, 100), R(0.6, 100), R(0.6, 140), and S(0.8, 130). 'Q' is the yield point, 'R' is the UTS point and, 'S' the fracture point.



The toughness of the material (in MJ/m^3) is ________.

Solution: Consider the figure given below:



Toughness = Area under the curve

1 + 2 + 3 + 4 + 5

$$= \frac{1}{2} \times \frac{0.2}{100} \times 100 + \frac{0.4}{100} \times 100 + \frac{0.2}{100} \times 130$$

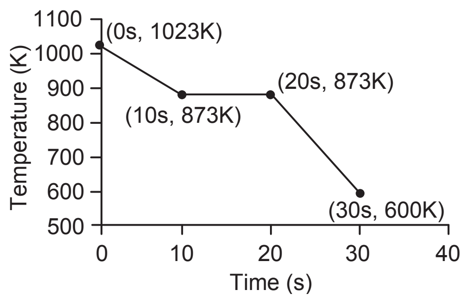
$$= \frac{1}{2} \times 10 \times \frac{0.2}{100} + \frac{1}{2} \times 40 \times \frac{0.4}{100} = 0.85 \text{ MJ/m}^3$$

Hence, the correct answer is 0.85.

Question Number: 59 **Question Type: NAT**

Heat is removed from a molten metal of mass 2 kg at a constant rate of 10 kW till it is completely solidified. The cooling curve is shown in the figure.

Assuming uniform temperature throughout the volume of the metal during solidification, the latent heat of fusion of the metal (in kJ/kg) is ________.



Solution: Mass of molten metal $m = 2$ kg

Constant rate $\dot{Q} = 10$ kW

Total heat removed during phase change

$= 10 \times 10 = 100$ kJ

Time =10 s

Latented heat $\frac{\text{kJ}}{\text{kg}} = \frac{100}{2} = 50\ \frac{\text{kJ}}{\text{kg}}$

Hence, the correct answer is 50.

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

The tool life equation for HSS tool is $VT^{0.14} f^{0.7} d^{0.4}$ = constant. The tool life (T) of 30 min is obtained using the following cutting conditions:

$V = 45$ m/min, $f = 0.35$ mm, $d = 2.0$ mm

If speed (V), feed (f) and depth of cut (d) are increased individually by 25%, the tool life (in min) is

(A) 0.15 (B) 1.06
(C) 22.50 (D) 30.0

Solution: The cutting conditions are given as

$V_1 = 45$ m/min

$f_1 = 0.35$ mm

$d_1 = 2$ mm

$T_1 = 30$ min

When the speed is increased individually by 25%, then we have cutting conditions as given below:

$V_2 = 1.25\ V_1$

$f_2 = 1.25\ f_1$

$d_1 = 1.25\ d_1$

$T_2 = ?$

Now we have $VT^{0.14} f^{0.7} d^{0.4} = C$

$$V_1 T_1^{0.14} f_1^{0.7} d_1^{0.4} = V_2 T_2^{0.14} f_2^{0.7} d_2^{0.4}$$

$$\Rightarrow T_1^{0.14} = 1.25 \times 1.25^{0.7} \times 1.25^{0.4}\ T_2^{0.14}$$

$$\therefore\ T_2 = \frac{30}{(1.25)^{2.1/0.14}} \approx 1.055 \approx 1.06$$

Hence, the correct option is (B).

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

A cylindrical job with diameter of 200 mm and height of 100 mm is to be cast using modulus method of riser design. Assume that the bottom surface of cylindrical riser does not contribute as cooling surface. If the diameter of the riser is equal to its height, then the height of the riser (in mm) is

(A) 150 (B) 200
(C) 100 (D) 125

Solution: Diameter of cylindrical job $d_{\text{casting}} = 200$ mm

Height of cylindrical job $h_{\text{casting}} = 100$ mm

We know that $d_{\text{riser}} = h_{\text{riser}}$

$$\left(\frac{V}{S.A}\right)_{\text{riser}} = 1.2\left(\frac{V}{S.A}\right)_{\text{casting}}$$

$$= \frac{\left(\frac{\pi}{4} d_{\text{riser}}^2\ h_{\text{riser}}\right)}{\pi\, d_{\text{riser}}\ h_{\text{riser}} + \frac{\pi}{4} d_{\text{riser}}^2}$$

$$= 1.2 \frac{\frac{\pi}{4} d_{\text{casting}}^2\ h_{\text{casting}}}{\pi d_{\text{casting}}\ h_{\text{casting}} + 2\frac{\pi}{4} d_{\text{casting}}^2}$$

$$\frac{4\,h_{\text{riser}}^3}{4\,\pi h_{\text{riser}}^2 + \pi\, h_{\text{riser}}^2} = \frac{1.2 \times 200^2 \times 100 \times 2}{2\,\pi 200 \times 100 + \pi \times 200^2}$$

$$\Rightarrow \frac{4\,h_{\text{riser}}}{5} = \frac{1.2 \times 200^2 \times 100 \times 2}{2 \times 200 \times 100 + 200^2}$$

$h_{\text{riser}} = 150$ mm

Hence, the correct option is (A).

Question Number: 62 **Question Type: NAT**

A 300 mm thick slab is being cold rolled using roll of 600 mm diameter. If the coefficient of friction is 0.08, the maximum possible reduction (in mm) is ________.

Solution: Thickness of slab $t_1 = 300$ mm

Diameter of roll $r = 300$ mm

Coefficient of friction $\mu = 0.08$

$t_2 = ?$

Now we know that

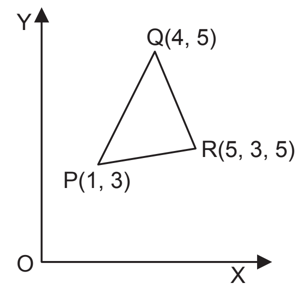
$t_1 - t_2 = \mu^2 R$ = max. possible reduction

$= 0.08^2 \times 300 = 1.92$ mm

Hence, the correct answer is 1.9 – 1.94 mm.

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

The figure below represents a triangle PQR with initial coordinates of the vertices as $P(1, 3)$, $Q(4, 5)$, and $R(5, 3, 5)$. The triangle is rotated in the X-Y plane about the vertex P by angle θ in the clockwise direction. If $\sin\theta = 0.6$ and $\cos\theta = 0.8$, then new coordinates of the vertex Q are



(A) (4.6, 2.8) (B) (3.2, 406)
(C) 7.9, 5.5) (D) (5.5, 7.9)

Solution: If we translate the point P to origin

New coordinates at P are (0, 0)

New coordinates of Q are (3, 2)

Now rotating PQ about P by θ

New coordinates of Q are

$$X^1 = x_Q \cos\theta + y_Q \sin\theta$$
$$= 3 \times 0.8 + 2 \times 0.6 = 3.6$$
$$Y^1 = -X_Q \sin\theta + y_Q \cos\theta$$
$$= -3 \times 0.6 + 2 \times 0.8 = -0.2$$

Now, again translating P to original condition,

New coordinates of the vertex Q becomes (3.6 + 1, 3 – 0.2) = (4.6, 2.8)

Hence, the correct option is (A).

Question Number: 64 **Question Type: NAT**

The annual demand for an item is 10,000 units. The unit cost is Rs. 100 and inventory carrying charges are 14.4% of the unit cost per annum. The cost of one procurement is Rs. 2000. The time between two consecutive orders to meet the above demand is __________ month(s).

Solution: Annual demand of item $D = 10{,}000$

Unit cost of item C = Rs. 100

Inventory carrying charges $C_h = 0.144 \times 10$

Cost of one procurement C_o = Rs. 2000

Now using the relation

$$EOQ = \sqrt{2D\frac{C_o}{C_h}} = \sqrt{\frac{2\times 10{,}000\times 2000}{0.144\times 100}}$$
$$= 1666.6667$$

$$\text{No. of orders} = \frac{10{,}000}{1666.6667} = 6$$

Time between orders

$$= \frac{\text{No. of month in a year}}{\text{No. of orders}} = \frac{12}{6} = 2$$

Hence, the correct answer is 2.

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

Maximize $Z = 15X_1 + 20X_2$ subject to

$$12X_1 + 4X_2 \geq 36$$
$$12X_1 - 6X_2 \leq 24$$
$$X_1, X_2 \geq 0$$

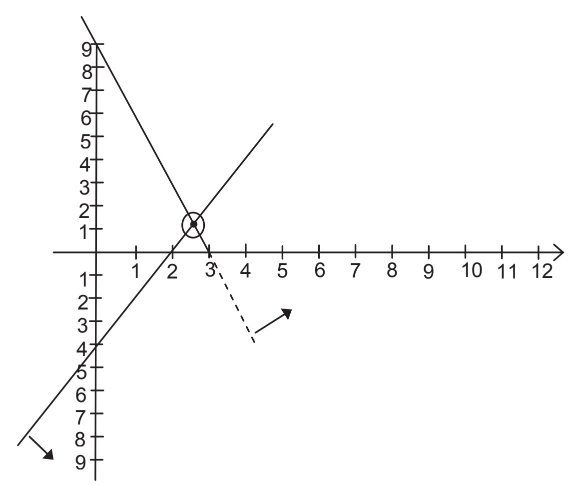
The above linear programming problem has

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

Solution: Maximize $Z = 15\,X_1 + 20\,X_2$

Subject to $12X_1 + 4X_2 \geq 36$

$12X_1 + 6X_2 \geq 36$



∴ The region is unbounded.

Hence, the correct option is (B).

GATE 2016 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 2 mark each and Q.6 to Q.10 carry 1 marks each.

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

Students taking an exam are divided into two groups, *P* and *Q* such that each group has the same number of students. The performance of each of the students in a test was evaluated out of 200 marks. It was observed that the mean of group *P* was 105, while that of group *Q* was 85. The standard deviation of group *P* was 25, while that of group *Q* was 5. Assuming that the marks were distributed on a normal distribution, which of the following statements will have the highest probability of being **TRUE**?

(A) No student in group *Q* scored fewer marks than any student in group *P*.
(B) No student in group *P* scored fewer marks than any student in group *Q*.
(C) Most students of group *Q* scored marks in a narrower range than students in group *P*.
(D) The median of the marks of group *P* is 100.

Solution: Consider the table given below:

	Q	*P*
Mean	85	105
Standard deviation	5	25

For *Q*, 68% of the scores are in the interval 80 – 90 and 99.7% of the scores are in the interval 70 – 100.

For *P*, 68% of the scores are in the interval 80 – 130.

99.7% of the scores are in the interval 30 – 180.

For option (A), the probability is 0.

For options (B, C), (B) starts with 'No student' while (C) begins with 'most students'. Even before reading the options completely, we can say that (C) is more probable than (B). But we do need to read the options completely. When we do that, we do not see anything to change our conclusion.

For option (D), the median of *P* is 100. For a normal distribution, the mean, median, and mode coincide, i.e. the median is actually 85. Therefore, the probability of (D) is 0.

Hence, the correct option is (C).

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

A smart city integrates all modes of transport, uses clean energy, and promotes sustainable use of resources. It also uses technology to ensure safety and security of the city, something which critics argue, will lead to a surveillance state.

Which of the following can be logically inferred from the above paragraph?

(i) All smart cities encourage the formation of surveillance states.
(ii) Surveillance is an integral part of smart city.
(iii) Sustainability and surveillance go hand-in-hand in a smart city.
(iv) There is a perception that smart cities promote surveillance.

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

Solution: We know that a smart city would lead to a surveillance state is merely the perception of critics; therefore, it cannot be said that sustainability and surveillance go hand-in-hand or surveillance is an integral part of a smart city. All smart cities encourage the formation of surveillance state; a surveillance state could be a possible outcome of a smart city. Hence, options (i), (ii), and (iii) are incorrect.

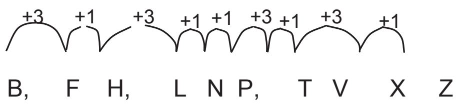
Hence, the correct option is (C).

Question Number: 3 **Question Type: MCQ**

Find the missing sequence in the letter series.
B, FH, LNP, __________.

(A) SUWY (B) TUVW
(C) TVXZ (D) TWXZ

Solution:



So, it is 'TVXZ'

Hence, the correct option is (C).

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

The binary operation o is defined a o $b = ab + (a + b)$, where a and b are any two real numbers. The value of the identity element of this operation, defined as the number x such that a o $x = a$, for any a, is ______.

(A) 0 (B) 1
(C) 2 (D) 10

Solution: The binary operation o is defined as

$a \square b = ab + (a + b)$

Let x be the identity element

i.e., $a \square x = ax + (a + x) = a$ for all values of a.

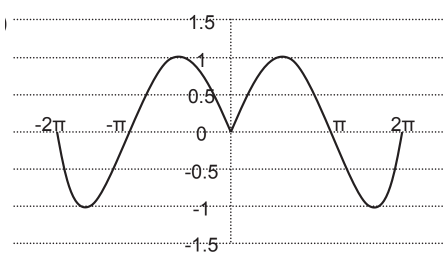
$\Rightarrow x(a + 1) = 0 \Rightarrow x = 0$ [The equality holds for all values of a and not just for $a = -1$.]

The identify element for this operation is 0.

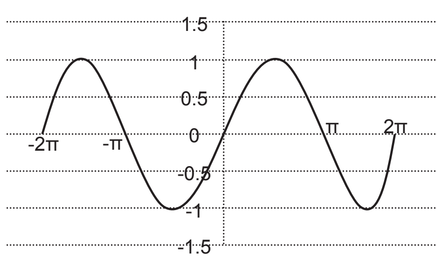
Hence, the correct option is (A).

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

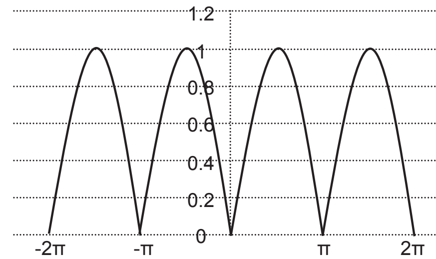
Which of the following curves represent the function $y = \ln(|e^{[|\sin(|x|)|]}|)$ for $|x| < 2\pi$? Here, x represents the abscissa and y represents the ordinate.



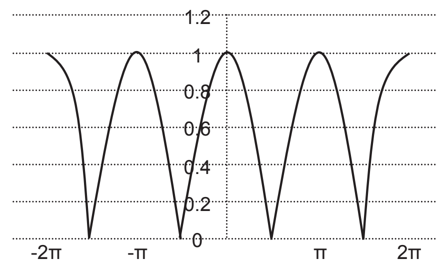
(A)



(B)



(C)



(D)

Solution: We have to identify the graph of

$$y = \ln\left(\left|e^{[|\sin|x||]}\right|\right)$$

for $|x| < 2\pi$.

(1) If $x = 0$, then $y = 0$. We can reject (D).
(2) Also y is an even function, i.e. $y(-a) = y(a)$. We can reject (B).
(3) We see that y depends on $|\sin|x||$(rather than $\sin|x|$). Therefore, for $x = \frac{3\pi}{4}$ and $\frac{5\pi}{4}$ (for example), y should have the same value. We can reject (A).

Hence, the correct option is (C).

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

The volume of a sphere of diameter 1 unit is ______ than the volume of a cube of side 1 unit.

(A) least (B) less
(C) lesser (D) low

Solution: The correct option is (B).

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

The unruly crowd demanded that the accused be______ without trial.

(A) hanged (B) hanging
(C) hankering (D) hung

Solution: The correct option is (A).

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

Choose the statement(s) where the underlined word is used correctly:

(i) A prone is a dried plum.
(ii) He was lying prone on the floor.
(iii) People who eat a lot of fat are prone to heart disease.

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

Solution: A dried plum is called a prune. Hence, statement (i) is incorrect. To lie prone is to lie prostrate. To be prone to a disease is to be liable or likely to suffer from. Hence, options (ii) and (iii) are correct.

Hence, the correct option is (D).

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

Fact: If it rains, then the field is wet.

Read the following statements:

(i) It rains.
(ii) The field is not wet.
(iii) The field is wet.
(iv) It did not rain.

Which one of the options given below is **NOT** logically possible, based on the given fact?

(A) If (iii), then (iv). (B) If (i), then (iii).
(C) If (i), then (ii). (D) If (ii), then (iv).

Solution: We know that

If $P \Rightarrow q$ p = it rains

then $\sim q \Rightarrow \sim P$ q = the field is wet

(A) If q, then p (we are not sure)
(B) If p, then q (TRUE)
(C) If p, then $\sim q$ (NOT POSSIBLE)
(D) If $\sim q$, then $\sim p$ (TRUE)

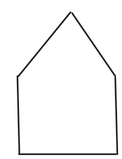
Hence, the correct option is (C).

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

A window is made up of a square portion and an equilateral triangle portion above it. The base of the triangular portion coincides with the upper side of the square. If the perimeter of the window is 6 m, the area of the window in m^2 is ________.

(A) 1.43 (B) 2.06
(C) 2.68 (D) 2.88

Solution: The window is shown in the figure below.



The boundary of the window is a pentagon, in which all the 5 sides are equal. As the perimeter is 6 m, each of these sides is 1.2 m. The area is $(1.2)^2 + \frac{\sqrt{3}}{4}(1.2)^2$.

$$= (1.44)\left(1+\frac{1.73}{4}\right) = (0.36)\,(5.73) \approx 2.06.$$

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 condition for which the eigenvalues of the matrix are positive is $A=\begin{bmatrix} 2 & 1 \\ 1 & k \end{bmatrix}$

(A) $k > 1/2$ (B) $k > -2$
(C) $k > 0$ (D) $k < -1/2$

Solution: Given matrix is $A=\begin{bmatrix} 2 & 1 \\ 1 & k \end{bmatrix}$

The eigenvalues of A are positive.

$\Rightarrow$ Sum of the eigenvalues of A is positive and the product of the eigenvalues of A is positive.

$\Rightarrow$ Trace $(A) > 0$ and Det $(A) > 0$

$\Rightarrow$ $2 + k > 0$ and $2k - 1 > 0$

$\Rightarrow$ $k > -2$ and $k > \frac{1}{2}$

$\Rightarrow$ $k >$

Hence, the correct option is (A).

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

The values of x for which the function is **NOT** continuous are $f(x)=\frac{x^2-3x-4}{x^2+3x-4}$.

(A) 4 and –1 (B) 4 and 1
(C) –4 and 1 (D) –4 and –1

Solution: Given $f(x)$ = $f(x)=\frac{x^2-3x-4}{x^2+3x-4}$.

As the numerator and the denominator of $f(x)$ are polynomials in x, $f(x)$ is not continuous at those values of x, where the denominator is zero.

$\therefore \quad x^2 + 3x - 4 = 0$

$\Rightarrow \quad (x + 4)(x - 1) = 0$

$\Rightarrow \quad x = -4, x = 1$

$\therefore f(x)$ is not continuous at $x = -4$ and $x = 1$

Hence, the correct option is (C).

Question Number: 13 **Question Type: MCQ**

Laplace transform of $\cos(\omega t)$ is

(A) $\dfrac{S}{S^2+\omega^2}$ (B) $\dfrac{\omega}{S^2+\omega^2}$

(C) $\dfrac{S}{S^2-\omega^2}$ (D) $\dfrac{\omega}{S^2-\omega^2}$

Solution: Standard result

Hence, the correct option is (A).

Question Number: 14 **Question Type: NAT**

A function f of the complex variable $z = x + iy$, is given as $f(x, y) = u(x, y) + i\,v(x, y)$, where $u(x, y) = 2kxy$ and $v(x, y) = x^2 - y^2$. The value of k, for which the function is analytic, is ________.

Solution: Given $f(x, y) = u(x, y) + iv(x, y)$

where $u(x, y) = 2k\,xy$ and $v(x, y) = x^2 - y^2$

$$\Rightarrow \frac{\partial u}{\partial x} = 2ky; \quad \frac{\partial u}{\partial y} = 2kx$$

and
$$\frac{\partial v}{\partial x} = 2x; \quad \frac{\partial v}{\partial y} = -2y$$

$f(x, y)$ is analytic $\Rightarrow f(x, y)$ satisfies Cauchy–Riemann equations.

$$\Rightarrow \frac{\partial u}{\partial x} = \frac{\partial v}{\partial v} \text{ and } \frac{\partial v}{\partial x} = -\frac{\partial u}{\partial y}$$

$\Rightarrow \quad 2ky = -2y$ and $2x = -2kx$

$\Rightarrow \quad \kappa = -1$

Hence, the correct answer is –1.

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

Numerical integration using trapezoidal rule gives the best result for a single variable function, which is

(A) linear (B) parabolic

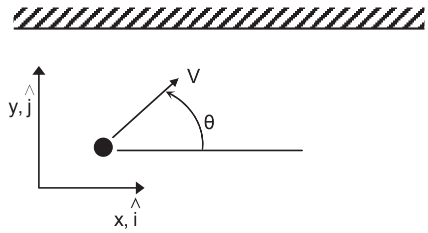
(C) logarithmic (D) hyperbolic

Solution: Standard result is linear.

Hence, the correct option is (A).

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

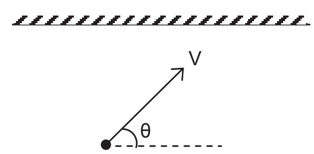
A point mass having mass M is moving with a velocity V at an angle θ to the wall as shown in the figure. The mass undergoes a perfectly elastic collision with the smooth wall and rebounds. The total change (final minus initial) in the momentum of the mass is



(A) $-2MV\cos\theta\,\hat{j}$ (B) $2MV\sin\theta\,\hat{j}$

(C) $2MV\cos\theta\,\hat{j}$ (D) $-2MV\sin\theta\,\hat{j}$

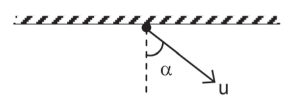
Solution:



Velocity of approach = $V\sin\theta$

If 'u' is the rebound velocity of the point mass making an angle 'α' with the vertical axis, then,

$$u\cos\alpha = -V\sin\theta$$



Total change in momentum, can be calculated using

$$\Delta P = M(V_2 - V_1)$$
$$= M(-V\sin\theta - V\sin\theta)$$
$$= -2\,MV\sin\theta$$

Hence, the correct option is (D).

Question Number: 17 **Question Type: MCQ**

A shaft with a circular cross-section is subjected to pure twisting moment. The ratio of the maximum shear stress to the largest principal stress is

(A) 2.0 (B) 1.0

(C) 0.5 (D) 0

Solution: As shaft is subjected to pure twisting moment, thus $\sigma_x = \sigma_y = 0$.

Now we have

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

$$\sigma_{1,2} = \pm\,\tau_{xy}$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{\tau_{xy} - (-\tau_{xy})}{2} = \tau_{xy}$$

$$\therefore \quad \frac{\tau_{max}}{\sigma_1} = \frac{\tau_{xy}}{\tau_{xy}} = 1$$

Hence, the correct option is (B).

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

A thin cylindrical pressure vessel with closed ends is subjected to internal pressure. The ratio of circumferential (hoop) stress to the longitudinal stress is

(A) 0.25 (B) 0.50
(C) 1.0 (D) 2.0

Solution: We know that for a thin cylindrical pressure vessel, ratio of circumferential (hoop) stress to the longitudinal stress is 2, that is

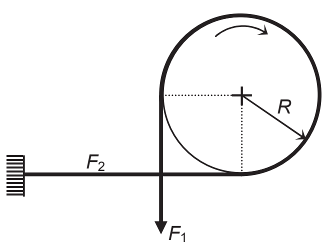
$$\frac{\sigma_h}{\sigma_l} = 2\,.$$

Hence, the correct option is (D).

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

The forces F_1 and F_2 in a brake band and the direction of rotation of the drum are as shown in the figure. The coefficient of friction is 0.25. The angle of wrap is 3 π/2 radians. It is given that R = 1 m and F_2 = 1 N. The torque (in N-m) exerted on the drum is __________.

Solution:



Radius R = 1 m

Force F_2 = 1 N

Angle of wrap $\theta = 3\pi/2$,

Coefficient of friction μ = 0.25

Now using the relation

$$\frac{F_1}{F_2} = e^{\mu\theta}$$

$$\therefore \quad \frac{F_1}{F_2} = e^{\left(0.5\times\frac{3\pi}{2}\right)} = 3.246$$

$$F_2 = 1 \text{ N}$$

$$\therefore \quad F_1 = 3.246 \text{ N}$$

The torque (in N-m) exerted on the drum will be

$$T = (F_1 - F_2)\,R$$
$$= (3.246 - 1) \times 1$$
$$= 2.246 \text{ Nm}$$

Hence, the correct answer is 2.2 to 2.3.

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

A single degree of freedom mass-spring-viscous damper system with mass m, spring constant k, and viscous damping coefficient q is critically damped. The correct relation among m, k, and q is

(A) $q = \sqrt{2km}$ (B) $q = 2\sqrt{km}$

(C) $q = \sqrt{\frac{2k}{m}}$ (D) $q = 2\sqrt{\frac{k}{m}}$

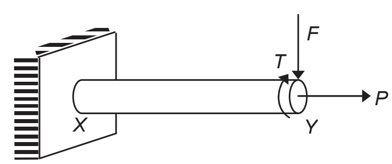
Solution: We know that for critically damped system q relation among m, k, and q is

$q_c = 2\sqrt{km}$.

Hence, the correct option is (C).

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

A machine element XY, fixed at end X, is subjected to an axial load P, transverse load F, and a twisting moment T at its free and Y. The most critical point from the strength point of view is



(A) a point on the circumference at location Y
(B) a point at the center at location Y
(C) a point on the circumference at location X
(D) a point at the center at location X

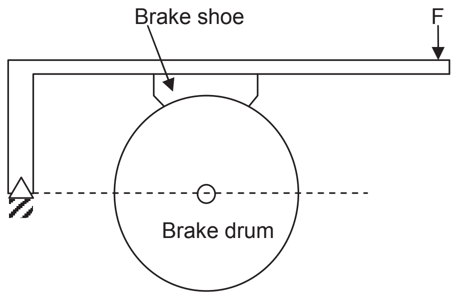
Solution: Outer fibers of the element XY will be at severe stress, location X will be stressed more than location Y as movement of X is restricted.

Hence, the correct option is (C).

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

For the brake shown in the figure, which one of the following is TRUE?

(A) Self energizing for clockwise rotation of the drum
(B) Self energizing for anti-clockwise rotation of the drum



(C) Self energizing for rotation in either direction of the drum
(D) Not of the self energizing type

Solution: Brake is said to be self-energizing when the moment of frictional force (μN) is in the same direction as that of the applied force (F).

Therefore, in the given case, the brake will be self energizing when the rotation of the drum is clockwise.

Hence, the correct option is (C).

Question Number: 23 **Question Type: MCQ**

The volumetric flow rate (per unit depth) between two streamlines having stream functions Ψ_1 and Ψ_2 is

(A) $|\Psi_1 + \Psi_2|$ (B) $\Psi_1 \Psi_2$
(C) Ψ_1 / Ψ_2 (D) $|\Psi_1 - \Psi_2|$

Solution: We know that the difference between two stream functions give volumetric flow rate, i.e.,

$$\dot{q} = |\Psi_1 - \Psi_2|.$$

Hence, the correct option is (C).

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

Assuming constant temperature condition and air to be an ideal gas, the variation in atmospheric pressure with height calculated from fluid static is

(A) linear (B) exponential
(C) quadratic (D) cubic

Solution: For an ideal gas at isothermal condition the variation in atmospheric pressure with height calculated from fluid static is exponential.

Hence, the correct option is (B).

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

A hollow cylinder has length L, inner radius r_1, outer radius r_2, and thermal conductivity k. The thermal resistance of the cylinder for radial conduction is

(A) $\dfrac{\ln(r_2/r_1)}{2\pi kL}$ (B) $\dfrac{\ln(r_1/r_2)}{2\pi kL}$

(C) $\dfrac{2\pi kL}{\ln(r_2/r_1)}$ (D) $\dfrac{2\pi kL}{\ln(r_1/r_2)}$

Solution: The thermal resistance of the cylinder for radial conduction is

$$R_{th} = \frac{\ln(r_2/r_1)}{2\pi kL}.$$

Hence, the correct option is (A).

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

Consider the radiation heat exchange inside an annulus between two very long concentric cylinders. The radius of the outer cylinder is R_o and that of the inner cylinder is R_i. The radiation view factor of the outer cylinder onto itself is

(A) $1 - \sqrt{\dfrac{R_i}{R_o}}$ (B) $\sqrt{1 - \dfrac{R_i}{R_o}}$

(C) $1 - \left(\dfrac{R_i}{R_o}\right)^{1/3}$ (D) $1 - \dfrac{R_i}{R_o}$

Solution: Radius of the outer cylinder = R_o

Radius of the inner cylinder= R_i.

We know that

$$F_{11} = 0$$
$$F_{11} + F_{12} = 1$$
$$\therefore \quad F_{12} = 1$$

Reciprocity theorem, $F_{12} A_1 = F_{21} A_2$

$$F_{21} = \frac{A_1}{A_2} = \frac{2\pi R_i L}{2\pi R_o L} = \frac{R_i}{R_o}$$

$$F_{22} = 1 - F_{21} = 1 - \frac{R_i}{R_o}.$$

Hence, the correct option is (D).

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

The internal energy of an ideal gas is a function of

(A) temperature and pressure
(B) volume and pressure
(C) entropy and pressure
(D) temperature only

Solution: The internal energy of an ideal gas is a function of temperature. Thus,

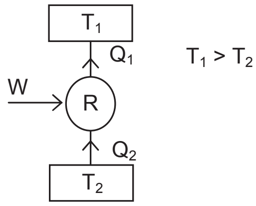
$$u = f(T).$$

Hence, the correct option is (D).

Question Number: 28 **Question Type: NAT**

The heat removal rate from a refrigerated space and the power input to the compressor are 7.2 kW and 1.8 kW, respectively. The coefficient of performance (COP) of the refrigerator is ________.

Solution: Heat removal rate, $Q_2 = 7.2$ kW



Power input to the compressor $W = 1.8$ kW

The coefficient of performance (COP) of the refrigerator can be calculated using the relation

$$(COP)_R = \frac{Q_2}{Q_2 - Q_1} = \frac{Q_2}{W}$$

$$= \frac{7.2}{1.8} = 4$$

Hence, the correct answer is 4.0.

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

Consider a simple gas turbine (Brayton) cycle and a gas turbine cycle with perfect regeneration. In both the cycles, the pressure ratio is 6 and the ratio of the specific heats of the working medium is 1.4. The ratio of minimum to maximum temperatures is 0.3 (with temperatures expressed in K) in the regenerative cycle. The ratio of the thermal efficiency of the simple cycle to that of the regenerative cycle is ________.

Solution: Pressure ratio $r = 6$,

Without regeneration

Ratio of the specific heat of the working medium $\gamma = 1.4$

Now using the relation

$$\eta_{\text{Brayton}} = 1 - \frac{1}{(r)^{\frac{\gamma-1}{\gamma}}}$$

$$= 1 - \frac{1}{(6)^{\frac{1.4-1}{1.4}}} = 0.4$$

With regeneration,

$$\text{Ratio } \frac{T_1}{T_3} = 0.3$$

Now using the relation

$$\eta_{\text{Brayton}} = 1 - \frac{T_1}{T_3} r^{\frac{\gamma-1}{\gamma}}$$

$$= 1 - (0.3)6^{\frac{1.4-1}{1.4}} = 0.5$$

Thus, the required ratio $= \frac{0.4}{0.5} = 0.8$.

Hence, the correct answer is 0.8.

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

In a single-channel queuing model, the customer arrival rate is 12 per hour and the serving rate is 24 per hour. The expected time that a customer is in queue is ______ minutes.

Solution: Customer arrival rate $\lambda = 12$/hour

Serving rate $\mu = 24$/hour

Now using the relation given below, expected time that a customer is in queue can be calculated as

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)}$$

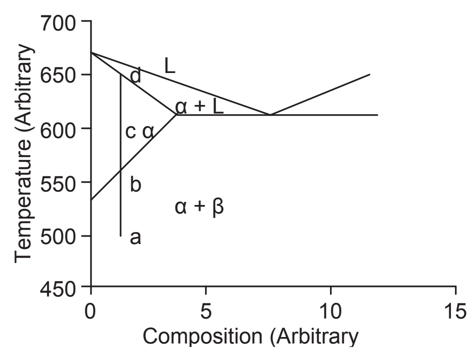
$$= \frac{12}{24(24-12)} = \frac{1}{24} \text{ hour}$$

$$= \frac{1}{24} \times 60 = 2.5 \text{ min}$$

Hence, the correct answer is 2.5.

Question Number: 31 **Question Type: MCQ**

In the phase diagram shown in the figure, four samples of the same composition are heated to temperatures marked by *a*, *b*, *c*, and *d*.



At which temperature will a sample get solutionized the fastest?

(A) a (B) b

(C) c (D) d

Solution: Maximum solubility occurs at point c.

Hence, the correct option is (C).

Question Number: 32 **Question Type: MCQ**

The welding process which uses a blanket of fusible granular flux is

(A) tungsten inert gas welding

(B) submerged arc welding

(C) electroslag welding

(D) thermit welding

Solution: Submerged arc welding (SAW) uses blanket of fusible granular flux.

Hence, the correct option is (B).

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

The value of true strain produced in compressing a cylinder to half its original length is

(A) 0.69 (B) –0.69
(C) 0.5 (D) –0.5

Solution: If L_o is the original length, it is given that

$$L = \frac{1}{2}L_o$$

Value of true strain produced in compressing will be

$$\epsilon_T = \ln\frac{L}{L_o} \quad \text{(for tension)}$$

$$\therefore \quad \epsilon_T = \ln\left(\frac{1}{2}\right) = -\ln 2$$

$$= -0.69$$

Hence, the correct option is (B).

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

The following data is applicable for a turning operation. The length of job is 900 mm, diameter of job is 200 mm, feed rate is 0.25 mm/rev, and optimum cutting speed is 300 m/min. The machining time (in min) is _________.

Solution: Length of job L = 900 mm

Diameter of job D = 200 mm

Feed rate f = 0.25 mm^2/rev

Optimum cutting speed V = 300 m/min

The machining time can be calculated using

$$t = \frac{\pi DL}{1000\,fV}$$

$$= \frac{\pi \times 200 \times 900}{1000 \times 0.25 \times 300} = 7.536 \text{ min}$$

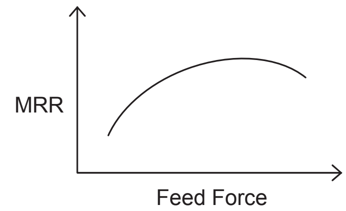
Hence, the correct answer is 7.5 to 7.6.

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

In an ultrasonic machining (USM) process, the material removal rate (MRR) is plotted as a function of the feed force of the USM tool. With increasing feed force, the MRR exhibits the following behavior:

(A) increases linearly
(B) decreases linearly
(C) does not change
(D) first increases and then decreases

Solution: With increasing feed force, the MRR first increases and then decreases as shown in the figure.



Hence, the correct option is (D).

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

A scalar potential ϕ has the following gradient: $\nabla\phi = yz\,\hat{i} + xz\,\hat{j} + xy\,\hat{k}$. Consider the integral $\int_C \nabla\phi \cdot d\vec{r}$ on the curve $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$.

The curve C is parameterized as follows:

$$\begin{cases} x = t \\ y = t^2 \\ z = 3t^2 \end{cases} \text{ and } \quad 1 \le t \le 3.$$

The value of the integral is ________.

Solution: Gradient of scalar potential is

$$\nabla\varphi = yz\bar{i} + xz\bar{j} + xy\bar{k}$$

And the given curve is

$$\bar{r} = x\bar{i} + y\bar{j} + z\bar{k}$$

$$\Rightarrow d\bar{r} = dx\bar{i} + dy\bar{j} + dz\bar{k}$$

The parametric form of the given curve C is

$x = t$, $y = t^2$, and $z = 3t^2$; $1 \le t \le 3$

$dx = dt$, $dy = 2tdt$, and $dz = 6tdt$

$$\therefore \int_C \nabla\varphi \cdot d\bar{r} = \oint_C \left(yz\bar{i} + xz\bar{j} + xy\bar{k}\right)\cdot\left(dx\bar{i} + dy\bar{j} + dz\bar{k}\right)$$

$$= \oint_C [yzdx + xzdy + xydz]$$

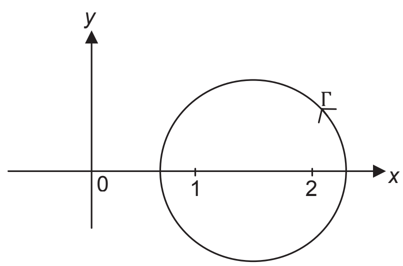
$$= \int_{t=1}^{3} \left[\left(t^2 \times 3t^2\right)dt + \left(t \times 3t^2\right)2tdt + \left(t \times t^2\right)6t\,dt\right]$$

$$= \int_{t=1}^{3} 15t^4 dt = 15 \times \frac{t^5}{5}\Bigg]_{t=1}^{3} = 726$$

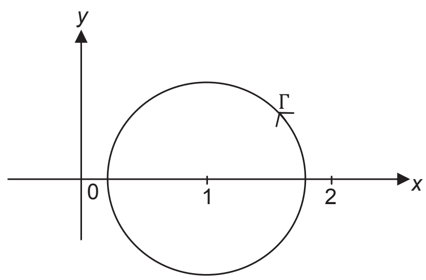
Hence, the correct answer is 726.

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

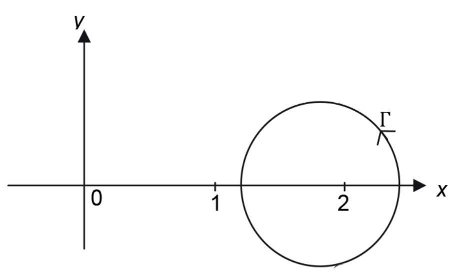
The value of $\oint_r \frac{3z-5}{(z-1)(z-2)}dz$ along a closed path Γ is equal to $(4\pi i)$, where $z = x + iy$ and $i = \sqrt{-1}$. The correct path Γ is



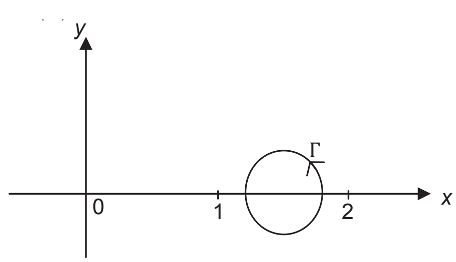
(A)



(B)



(C)



(D)

Solution: Consider the integral

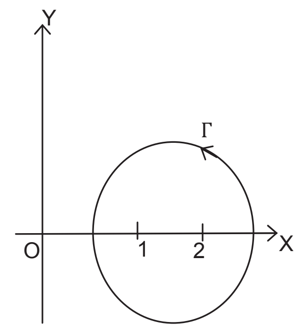
$$I = \oint_{\Gamma} \frac{3z-5}{(z-1)(z-2)} dz$$

If $\qquad g(z) = \dfrac{3z-5}{(z-1)(z-2)}$

$z = 1$ and $z = 2$ are the singularities of $g(z)$.

For option (A):

From the figure, we conclude that here both the singularities are inside the closed path Γ.



$$\therefore\ I = \oint_{\Gamma} \frac{3z-5}{(z-1)(z-2)} dz$$

$$= \oint_{\Gamma} \left[\frac{2}{z-1} + \frac{1}{z-2}\right] dz \quad \oint_{\Gamma} \frac{2}{(z-1)} dz + \oint_{\Gamma} \frac{1}{z-2} dz$$

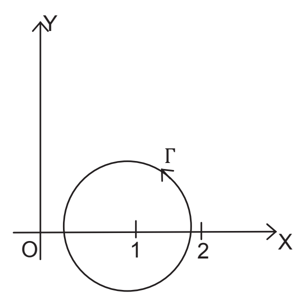
$$= 2\pi i \times 2 + 2\pi i \times 1$$

(By Cauchy's integral formula)

$$\therefore\ I = 5\pi i \neq 4\pi i$$

For Option (B):

From the figure given below, we conclude that here the singularity $z = 1$ only lies inside Γ.



$$\therefore\ \oint_{\Gamma} \frac{3z-5}{(z-1)(z-2)} dz = \oint_{\Gamma} \frac{(3z-5)/(z-2)}{(z-1)} dz$$

$$= 2\pi i \cdot f(z_0), \text{ where } f(z) = \frac{3z-5}{z-1}$$

and $z_0 = 1$

(By Cauchy's integral formula)

$$\therefore\ I = 4\pi i$$

Hence, the correct option is (B).

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

The probability that a screw manufactured by a company is defective is 0.1. The company sells screws in packets containing 5 screws and gives a guarantee of replacement if one or more screws in the packet are found to be defective. The probability that a packet would have to be replaced is _______.

Solution: If random variable X is defined by 'The number of defective screws in a packet of 5'.

Then clearly X follows binomial distribution with 'Drawing a defective screw' as success.

Probability that a screw manufactured by a company is defective $p = 0.1$

$$q = 1 - p = 0.9$$

Probability that a packet of 5 screws would have to be replaced = Probability that the packet contains one or more defective screws.

$$= P\,(X < 1) = 1 - P(X < 1)$$
$$= 1 - P(X = 0) = 1 - P(0;\, 5,\, 0.1)$$
$$= 1 - 5C_o (0.1)^0\,(0.9)^5 = 0.4095$$

Hence, the correct option is 0.4095.

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

The error in numerically computing the integral $\int_0^{\pi} (\sin x + \cos x)\,dx$ using the trapezoidal rule with three intervals of equal length between 0 and π is ______.

Solution: Let $I = \int_0^{\pi} (\sin x + \cos x)\,dx$

Exact value of I:

(Value of I by the analytical method)

$$I = \int_0^{\pi} (\sin x + \cos x)\,dx = -\cos x + \sin x \Big]_0^{\pi}$$
$$= (-\cos\pi) - (-\cos 0 + \sin 0)$$
$$\therefore\ I = \int_0^{\pi} (\sin x + \cos x)\,dx = 2 \qquad (1)$$

Value of I by the trapezoidal rule

Here $a = 0$ and $b = \pi$

The number of sub-intervals = $n = 3$

$$\therefore\ h = \frac{b-a}{n} = \frac{\pi}{3}$$

Let $y = f(x) = \sin x + \cos x$

x	0	$\frac{\pi}{3}$	$\frac{2\pi}{3}$	π
$y = f(x)$	1	1.3660	0.3660	–1

By trapezoidal rule, we have

$$\int_{\sigma}^{b} y\,dx = \frac{h}{2}\left[(y_0 + y_3) + 2(y_1 + y_2)\right]$$

$$\therefore\ I = \int_0^{\pi} (\sin x + \cos x)\,dx$$

$$= \frac{(\pi/3)}{2}\left[(1 + (-1)) + 2(1.3660 + 0.3660)\right] = 1.8137$$

$$\therefore\ I = \int_0^{\pi} (\sin x + \cos x)\,dx = 1.8137 \qquad (2)$$

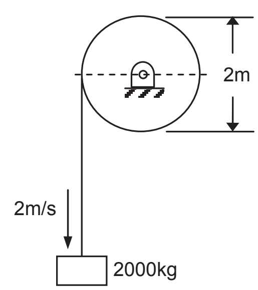
∴ From Eqs. (1) and (2),

$$\text{Error} = 2 - 1.8137$$
$$= 0.1863$$

Hence, the correct answer is 0.1863.

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

A mass of 2000 kg is currently being lowered at a velocity of 2 m/s from the drum as shown in the figure. The mass moment of inertia of the drum is 150 kg-m^2. On applying the brake, the mass is brought to rest in a distance of 0.5 m. The energy absorbed by the brake (in kJ) is _______.



Solution: Mass m = 20,000 kg

Velocity v = 2 m/s

Mass moment of inertia of drum I = 150 kg-m^2

Distance h = 0.5 m

Angular speed

$$\omega = \frac{v}{r} = \frac{2}{1} = 2\ \text{rad/s},$$

The energy absorbed by the brake (in kJ) will be

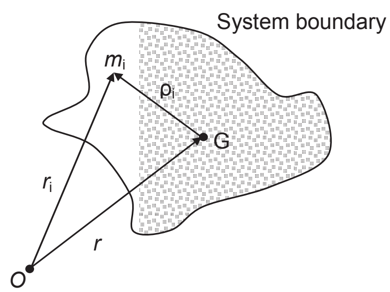
$$E = mgh + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$
$$= 14.1 \text{ kJ}$$

Hence, the correct answer is 14.1 to 14.3.

Question Number: 41 **Question Type: MCQ**

A system of particles in motion has mass center G as shown in the figure. The particle i has mass m_i and its position with respect to a fixed point O is given by the position vector r_i. The position of the particle with respect to G is given by the vector ρ_i. The time rate of change of the angular momentum of the system of particles about G is

(The quantity $\ddot{\rho}_i$ indicates second derivative of ρ_i with respect to time and likewise for r_i).



(A) $\Sigma_i\, r_i \times m_i \ddot{\rho}_i$ (B) $\Sigma_i \rho_i \times m_i \ddot{r}_i$

(C) $\Sigma_i\, r_i \times m_i \ddot{r}_i$ (D) $\Sigma_i\, \rho_i \times m_i \ddot{\rho}_i$

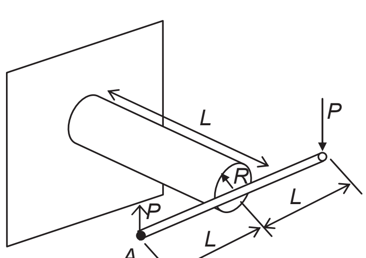
Solution: Rate of change of angular momentum of system about

$$G = \Sigma_i \frac{d}{dt}(mvr) = \Sigma_i \frac{d}{dt}(m_i \dot{r}_i \rho_i)$$
$$= \Sigma_i\, m_i \ddot{r}_i \rho_i$$

Hence, the correct option is (B).

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

A rigid horizontal rod of length $2L$ is fixed to a circular cylinder of radius R as shown in the figure. Vertical forces of magnitude P are applied at the two ends as shown in the figure. The shear modulus for the cylinder is G and the Young's modulus is E.



The vertical deflection at point A is

(A) $PL^3/(\pi R^4 G)$ (B) $PL^3/(\pi R^4 E)$
(C) $2PL^3/(\pi R^4 E)$ (D) $4PL^3/(\pi R^4 G)$

Solution: We know that

$$\text{Torque } (\tau) = P \times 2L$$
$$\frac{T}{J} = \frac{G\theta}{L}$$
$$\theta = \frac{TL}{JG}$$
$$\text{Deflection} = L\theta$$
$$\therefore \quad \text{Deflection} = \frac{TL^2}{JG}$$
$$= \frac{(P \times 2L)L^2}{\frac{\pi}{32}(2R)^4 \times G} = \frac{4PL^3}{\pi R^4 G}$$

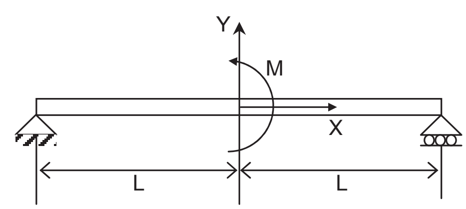
Hence, the correct option is (D).

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

A simply supported beam of length $2L$ is subjected to a moment M at the mid-point $x = 0$ as shown in the figure. The deflection in the domain $0 \le x \le L$ is given by

$$W = \frac{-Mx}{12EIL}(L - x)(x + c)$$

where E is the Young's modulus, I is the area momentum of inertia, and c is a constant (to be determined).



The slope at the center $x = 0$ is

(A) $ML/(2EI)$ (B) $ML/(3EI)$
(C) $ML/(6EI)$ (D) $ML/(12EI)$

Solution: $R_A = \frac{M}{2L}$, $R_B = -\frac{M}{2L}$

Bending moment at section X-X at x, from center C is

$$M_x = R_B(L - x) = \frac{-M}{2L}(L - x)$$
$$\frac{d^2y}{dx^2} = \frac{M_x}{EI} = \frac{-M}{2EIL}(L - x)$$
$$\frac{dy}{dx} = \frac{-M}{2EIL}\frac{(L - x)^2}{2}(-1) + C_1$$

$$y = \frac{M}{4EIL}\frac{(L-x)^3}{(-3)} + C_1x + C_2$$

$$= \frac{-M(L-x)^3}{12EIL} + C_1x + C_2$$

Boundary conditions:

1. $x = 0, y = 0$
2. $x = L, y = 0$

$$y_{(x=0)} = \frac{-ML^3}{12EIL} + C_2 = 0$$

$$\therefore \quad C_2 = \frac{ML^2}{12EI}$$

and

$$y_{(x=L)} = C_1L + C_2 = 0$$

$$\therefore \quad C_1 = \frac{-C_2}{L} = \frac{-ML}{12EI}$$

Thus,

$$y = \frac{-M}{12EIL}(L-x)^3 - \frac{ML(x)}{12EI} + \frac{ML^2}{12EI}$$

$$= \frac{-M}{12EIL}(L^3 - 3L^2x + 3Lx^2 - x^3 + L^2x - L^3)$$

$$= \frac{-M}{12EIL}(-2L^2x + 3Lx^2 - x^3)$$

$$= \frac{-Mx}{12EIL}(-2L^2 + 3Lx - x^2)$$

$$= \frac{-Mx}{12EIL}\left\{(-2L^2 + 2Lx + Lx - x^2)\right\}$$

$$= \frac{-Mx}{12EIL}\left\{-2L(L-x) + x(L-x)\right\}$$

$$= \frac{-Mx}{12EIL}(L-x)(x-2L)$$

Comparing the above equation with the expression for deflection,

$$w = \frac{-Mx}{12EIL}(L-x)(x+c)$$

We get $C = -2L$

$$\text{Slope } \theta = \frac{dw}{dx}$$

$$= \frac{d}{dx}\left\{\frac{-Mx}{12EIL}(Lx + Lc - x^2 - xc)\right\}$$

$$= \frac{-Mx}{12EIL}(L - 2x - c) + (Lx + Lc - x^2 - xc)\left(\frac{-M}{12EIL}\right)$$

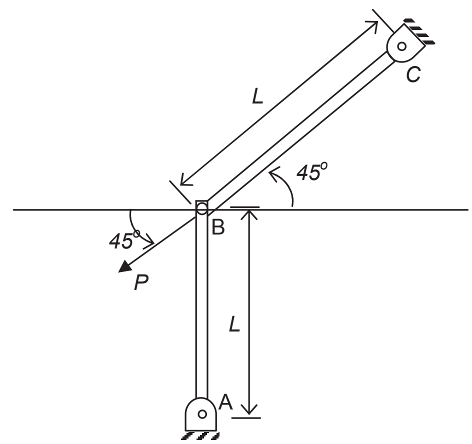
$$\theta_{(x=0)} = 0 + (Lc)\left(\frac{-M}{12EIL}\right)$$

$$= \frac{-Mc}{12EI} = \frac{ML}{6EI}$$

Hence, the correct option is (C).

Question Number: 44 **Question Type: NAT**

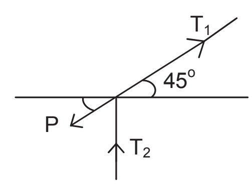
In the figure, the load $P = 1$ N, length $L = 1$ m, Young's modulus $E = 70$ GPa, and the cross-section of the links is a square with dimension 10 mm × 10 mm. All joints are pin joints.



The stress (in Pa) in the link AB is ________.

(Indicate compressive stress by a negative sign and tensile stress by a positive sign.)

Solution: Consider the free-body diagram, given below:



$$T_1 \cos 45 = P \cos 45$$

$$T_1 = P = 1 \text{ N}$$

$$T_1 \sin 45 = P \sin 45 - T_2$$

$$T_2 = 0$$

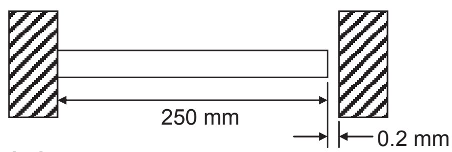
Since tension in link AB (T_2) is zero, hence stress will also be zero.

Hence, the correct answer is 0.

Question Number: 45 **Question Type: NAT**

A circular metallic rod of length 250 mm is placed between two rigid immovable walls as shown in the figure. The rod is in perfect contact with the wall on the left side and there is a gap of 0.2 mm between the rod and the wall on the right side. If the temperature of the rod is increased by 200°C, the axial stress developed in the rod is ______ MPa.

Young's modulus of the material of the rod is 200 GPa and the coefficient of thermal expansion is 10^{-5} per °C.



Solution: Length of metallic rod L = 250 mm,

Change in temperature ΔT = 200°C,

Coefficient of thermal expansion $\alpha = 10^{-5}$/°C

Young's modulus of the material of the rod = 200 GPa

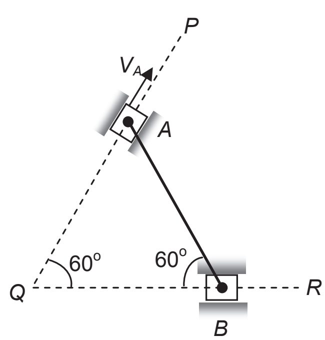
Now we know that

$$\delta l = \alpha \Delta T L = 0.5 \text{ mm}$$
$$(\delta l)_{net} = 0.5 - 0.2 = 0.3$$
$$\Sigma_T = \frac{(\delta l)_{net}}{L} = \frac{0.3}{250}$$
$$\sigma_T = E \in_T$$
$$= 200 \times 10^3 \times \frac{0.3}{250}$$
$$= 240 \text{ MPa}$$

Hence, the correct answer is 240.

Question Number: 46 **Question Type: NAT**

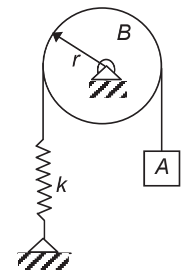
The rod AB, of length 1 m, shown in the figure is connected to two sliders at each end through pins. The sliders can slide along QP and QR. If the velocity V_A of the slider at A is 2 m/s, the velocity of the midpoint of the rod at this instant is _______ m/s.



Solution: Hence, the correct answer is 0.95 to 1.05.

Question Number: 47 **Question Type: NAT**

The system shown in the figure consists of block A of mass 5 kg connected to a spring through a mass less rope passing over pulley B of radius r and mass 20 kg. The spring constant k is 1500 N/m. If there is no slipping of the rope over the pulley, the natural frequency of the system is _____ rad/s.



Solution: Using energy method

$$\frac{dE}{dt} = 0$$

$$E = \frac{1}{2} I_o \omega^2 + \frac{1}{2} m v^2 + \frac{1}{2} k x^2$$

$$= \frac{1}{2}\left(\frac{Mr^2}{2}\right) - \dot{\theta}^2 + \frac{1}{2} m (r\dot{\theta})^2 + \frac{1}{2} k (r\theta)^2$$

$$\frac{dE}{dt} = \frac{1}{2}\left(\frac{Mr^2}{2} \times 2\dot{\theta}\ddot{\theta} + mr^2\left(2\dot{\theta}\ddot{\theta}\right) + kr^2\left(2\theta\dot{\theta}\right)\right) = 0$$

$$\frac{Mr^2}{2}\ddot{\theta} + mr^2\ddot{\theta} + kr^2\theta = 0$$

$$\left(m + \frac{M}{2}\right)\ddot{\theta} + k\theta = 0$$

$$\omega_n = \sqrt{\frac{k}{m + M/2}} = \sqrt{\frac{1500}{5+10}} = 10 \text{ rad/s}$$

Hence, the correct answer is 10.

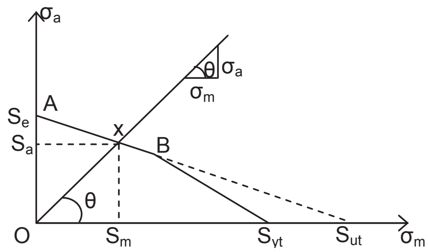
Question Number: 48 **Question Type: MCQ**

In a structural member under fatigue loading, the minimum and maximum stresses developed at the critical point are 50 MPa and 150 MPa, respectively. The endurance, yield, and the ultimate strengths of the material are 200 MPa, 300 MPa, and 400 MPa, respectively. The factor of safety using modified Goodman criterion is

(A) $\frac{3}{2}$ (B) $\frac{8}{5}$

(C) $\frac{12}{7}$ (D) 2

Solution: Minimum stresses σ_{min} = 50 MPa



Maximum stresses σ_{max} = 150 MPa

$$\sigma_a = \frac{150-50}{2} = 50 \text{ MPa}$$

$$\sigma_m = \frac{150+50}{2} = 100 \text{ MPa}$$

Endurance strength S_e = 200 MPa,

Yeild strength S_{yt} = 300 MPa

Ultimate strength S_{ut} = 400 MPa

$$\tan\theta = \frac{\sigma_a}{\sigma_m} = 0.5$$

Equation of line *AB*,

$$\frac{S_a}{S_e} + \frac{S_m}{S_{ut}} = 1$$

$$\frac{S_a}{200} + \frac{S_m}{400} = 1$$

$$2S_a + S_m = 400 \quad (1)$$

Equation of line OX,

$$\frac{S_a}{S_m} = \tan\theta = 0.5 \quad (2)$$

Solving Eqs. (1) and (2), we get

$$S_a = 100 \text{ MPa}, S_m = 200 \text{ MPa}$$

Now,

$$\sigma_a = \frac{S_a}{(fos)}$$

$$fos = \frac{S_a}{\sigma_a} = \frac{100}{50} = 2$$

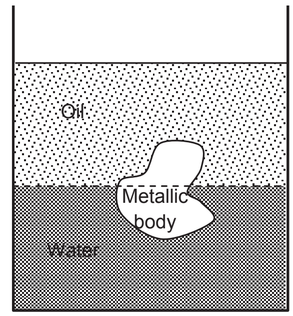
Hence, the correct option is (D).

Question Number: 49 **Question Type: NAT**

The large vessel shown in the figure contains oil and water. A body is submerged at the interface of oil and water such that 45% of its volume is in oil while the rest is in water. The density of the body is ______ kg/m^3.

The specific gravity of oil is 0.7 and the density of water is 1000 kg/m^3.

Acceleration due to gravity *g* = 10 m/*s*^{2}



Specific gravity of oil = 0.7

Density of water = 1000 kg/m^3

Solution: Let the density of the body be ρ_b.

Now using the relation

$$(\rho V)_{body} = (\rho V)_{water} + (\rho V)_{oil}$$

$$\rho_b V = (1000)(0.55)V + 700 \times (0.45)V$$

$$\rho_b = 550 + 315$$

$$= 865 \text{ kg/m}^3$$

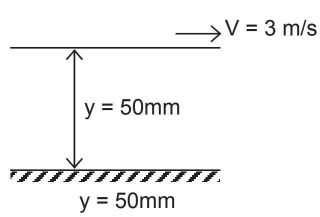
Hence, the correct answer is 865.

Question Number: 50 **Question Type: NAT**

Consider fluid flow between two infinite horizontal plates which are parallel (the gap between them being 50 mm). The top plate is sliding parallel to the stationary bottom plate at a speed of 3 m/s. The flow between the plates is solely due to the motion of the top plate. The force per unit area (magnitude) required to maintain the bottom plate stationary is ______ N/m^2.

Viscosity of the fluid μ = 0.44 kg/m-s and density ρ = 88 kg/m^3.

Solution:



Viscosity of the fluid μ = 0.44 kg/m·s

Density of fluid ρ = 88 kg/m^3

The force per unit area (magnitude) required to maintain the bottom plate stationary will be

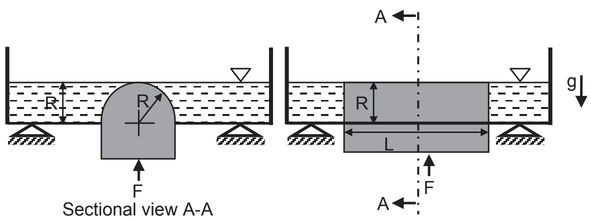
$$\frac{F}{A} = \tau = \frac{\mu V}{y} = \frac{0.44\times 3}{0.05}$$

$$= 26.4 \text{ N/m}^2$$

Hence, the correct answer is 26.4.

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

Consider a frictionless, mass less, and leak-proof plug blocking a rectangular hole of dimensions $2R \times L$ at the bottom of an open tank as shown in the figure. The head of the plug has the shape of a semi-cylinder of radius R. The tank is filled with a liquid of density ρ up to the tip of the plug. The gravitational acceleration is g. Neglect the effect of the atmospheric pressure.

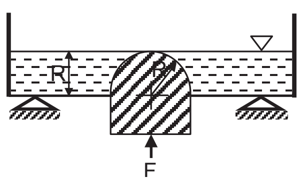


The force F required to hold the plug in its position is

(A) $2\rho R^2 gL\left(1-\frac{\pi}{4}\right)$ (B) $2\rho R^2 gL\left(1+\frac{\pi}{4}\right)$

(C) $\pi R^2 \rho gL$ (D) $\frac{\pi}{2}\rho R^2 gL$

Solution: Consider the figure given below:



Neglecting mass of plug,

Net Buoyancy force = $S_g(V_{net})$

Now using the relation

$$V_{net} = (2R \times L)R - \frac{\pi R^2 L}{2}$$

$$= 2R^2 L\left(1-\frac{\pi}{4}\right)$$

The force F required to hold the plug in its position is

$$\therefore \quad F_B = 2R^2 L\, \rho_g \left(1-\frac{\pi}{4}\right)$$

$$F_B = F = 2\rho R^2 gL\left(1-\frac{\pi}{4}\right)$$

Hence, the correct option is (A).

Question Number: 52 **Question Type: NAT**

Consider a parallel-flow heat exchanger with area A_p and a counter-flow heat exchanger with area A_c. In both the heat exchangers, the hot stream flowing at 1 kg/s cools from 80°C to 50°C. For the cold stream in both the heat exchangers, the flow rate and the inlet temperature are 2 kg/s and 10°C, respectively. The hot and cold streams in both the heat exchanges are of the same fluid. Also, both the heat exchangers have the same overall heat transfer coefficient. The ratio A_c/A_p is __________.

Solution: Flow rate of hot stream = 1 kg/s

Change in temperature of hot stream $T_{h1} - T_{h2} = 80 - 50 = 30°C$

Flow rate of cold stream = 2 kg/s

Change in temperature of cold stream $T_{h1} - T_{c2} = 80 - 50 = 30°C$

As specific heat of cold and hot stream is same, therefore ($\epsilon_P = \epsilon_C = \epsilon_{P,C}$)

$$R = \frac{C_{min}}{C_{max}} = \frac{1}{2} = 0.5$$

$$\epsilon_P = \frac{1-\exp\left(-NTU\left(1+R\right)\right)}{1+R} \qquad (1)$$

Also, for cold

$$\epsilon_{P,C} = \frac{T_{h_1} - T_{h_2}}{T_{h_1} - T_{c_1}} = \frac{80-50}{80-10}$$

$$\epsilon_{P,C} = \frac{3}{7} \qquad (2)$$

Form Eqs. (1) and (2)

$$\frac{3}{7} = \frac{1-\exp\left(-NTU\times 1.5\right)}{1.5}$$

$$(NTU)_P = 0.686$$

$$\epsilon_c = \frac{1-\exp\left(-NTU\left(1-R\right)\right)}{1-R\exp\left(-NTU\left(1-R\right)\right)}$$

$$\frac{3}{7} = \frac{1-\exp\left(-0.5\,NTU\right)}{1-0.5\exp\left(-0.5\,NTU\right)}$$

$$(NTU)_C = 0.637$$

$$NTU = \frac{UA}{C_{min}}$$

Now we have

$$U_C = U_P$$

$$\therefore \frac{(NTU)_C}{(NTU)_P} = \frac{A_C}{A_P}$$

$$\Rightarrow \frac{A_C}{A_P} = \frac{0.637}{0.686} = 0.928 = 0.93$$

Hence, the correct answer is 0.93.

Question Number: 53 **Question Type: NAT**

Two cylindrical shafts *A* and *B* at the same initial temperature are simultaneously placed in a furnace. The surfaces of the shafts remain at the furnace gas temperature at all times after they are introduced into the furnace. The temperature variation in the axial direction of the shafts can be assumed to be negligible. The data related to shafts *A* and *B* is given in the following table.

Quantity	Shaft A	Shaft B
Diameter (m)	0.4	0.1
Thermal conductivity (W/m-K)	40	20
Volumetric heat capacity (J/m^3-K)	2×10^6	2×10^7

The temperature at the centerline of the shaft *A* reaches 400°C after two hours. The time required (in hours) for the centerline of the shaft *B* to attain the temperature of 400°C is ______.

Solution: Volumetric heat capacity (J/m^3-K) for shaft *A* $(\rho C)_A = 2 \times 10^6$ J/m^{3}K.

Volumetric heat capacity (J/m^3-K) for shaft *B* $(\rho C)_B = 2 \times 10^7$ J/m^{3}K

At the center of cylinder of radius *r*, temperature is

$$\frac{\theta}{\theta_i} = \text{erf}\left(\frac{\alpha\tau}{r^2}\right)$$

In the above relation, $\alpha = \dfrac{k}{\rho C}$

We know that $\dfrac{\theta}{\theta_i}$ is constant for both shafts.

$$\therefore \quad \left(\frac{\alpha\tau}{r^2}\right)_1 = \left(\frac{\alpha\tau}{r^2}\right)_2$$

$$\tau_2 = 2.5 \text{ hours}$$

Hence, the correct answer is 2.5.

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

A piston-cylinder device initially contains 0.4 m^3 of air (to be treated as an ideal gas) at 100 kPa and 80°C. The air is now isothermally compressed to 0.1 m^3. The work done during this process is _______ kJ.

(Take the sign convention such that work done on the system is negative)

Solution: Initial volume of air $V_1 = 0.4$ m^3

Initial volume of air $V_2 = 0.1$ m^3

We know that for isothermal process, work done,

$$W = P_1 V_1 \ln\frac{V_2}{V_1}$$

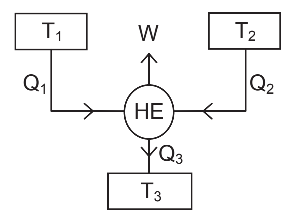
$$= 100 \times 0.4 \ln\frac{0.1}{0.4} \text{ kJ} = -55.45 \text{ kJ}$$

Hence, the correct answer is –55.6 to –55.4.

Question Number: 55 **Question Type: NAT**

A reversible cycle receives 40 kJ of heat from one heat source at a temperature of 127°C and 37 kJ from another heat source at 97°C. The heat rejected (in kJ) to the heat sin *k* at 47°C is _______.

Solution:



Heat $Q_1 = 40$ kJ

Heat $Q_2 = 37$ kJ

Temperature $T_1 = 127 + 273 = 400$ K

Temperature $T_2 = 97 + 273 = 370$ K

Temperature $T_3 = 47 + 273 = 320$ K

For reversible cycle

$$\frac{Q_1}{T_1} + \frac{Q_2}{T_2} = \frac{Q_3}{T_3}$$

$$\frac{40}{400} + \frac{37}{370} = \frac{Q_3}{320}$$

$$\frac{Q_3}{320} = 0.2$$

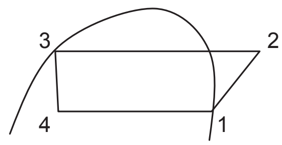
$$Q_3 = 320 \times 0.2$$

$$= 64 \text{ kJ}$$

Hence, the correct answer is 64.

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

A refrigerator uses R-134a as its refrigerant and operates on an ideal vapor-compression refrigeration cycle between 0.14 MPa and 0.8 MPa. If the mass flow rate of the refrigerant is 0.05 kg/s, the rate of heat rejection to the environment is _________ kW.



Given data:

At P = 0.14 MPa, h = 236.04 kJ/kg, s = 0.9322 kJ/kg-K

At P = 0.8 MPa, h = 272.05 kJ/kg (superheated vapor)

At P = 0.8 MPa, h = 93.42 kJ/kg (saturated liquid)

Solution: Mass flow rate of the refrigerant $\dot{m}$ = 0.05 kg/s

For superheated vapor h_2 =272.05 kJ/kg

For saturated liquid h_3 = 93.42 kJ/kg

Now heat rejected to atmosphere

$$Q = \dot{m}\,(h_2 - h_3)$$
$$= 0.05(272.05 - 93.42)$$
$$= 8.93 \text{ kW}$$

Hence, the correct answer is 8.9 to 8.95.

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

The partial pressure of water vapor in a moist air sample of relative humidity 70% is 1.6 kPa, the total pressure being 101.325 kPa. Moist air may be treated as an ideal gas mixture of water vapor and dry air. The relation between saturation temperature (T_s in K) and saturation pressure (p_s in kPa) for water is given by $\ln(p_s/p_o) = 14.317 - 5304/T_s$, where p_o = 101.325 kPa. The dry bulb temperature of the moist air sample (in °C) is _________.

Solution: Relative humidity $\Phi = 0.7$

Now we know that

$$\Phi = \frac{P_v}{P_{vs}}$$

$$P_{vs} = P_v/\Phi = 2.285 \text{ kPa}$$

Now using the relation

$$\ln\frac{P_s}{P_o} = 14.317 - \frac{5304}{T_s}$$

$$\ln\frac{2.285}{101.325} = 14.317 - \frac{5304}{T_s}$$

The dry bulb temperature of the moist air sample will be

$$T_s = 292.9 \text{ K} = 19.9^{o}\text{C}$$

Hence, the correct answer is 19.9.

Question Number: 58 **Question Type: MCQ**

In a binary system of A and B, a liquid of 20% A (80% B) is coexisting with a solid of 70% A (30% B). For an overall composition having 40% A, the fraction of solid is

(A) 0.40 (B) 0.50
(C) 0.60 (D) 0.75

Solution: Using lever rule,

$$W_\alpha + W_L = 1 \quad (1)$$
$$W_\alpha C_\alpha + W_L C_L = C_o$$
$$W_\alpha (0.7) + W_L(0.2) = 0.4 \quad (2)$$

Solving Eqs. (1) and (2), we get

$$W_\alpha = 0.4, W_L = 0.6$$

Thus, fraction of solid = 0.4

where W_α is fraction of solid and W_L is fraction of liquid, C is composition.

Hence, the correct option is (A).

Question Number: 59 **Question Type: NAT**

Gray cast iron blocks of size 100 mm × 50 mm × 10 mm with a central spherical cavity of diameter 4 mm are sand cast. The shrinkage allowance for the pattern is 3%. The ratio of the volume of the patter to the volume of the casting is __________.

Solution: Shrinkage allowance = 3% = 0.03

Volume of casting

$$V_c = (100 \times 50 \times 10) - \left(\frac{4}{3}\pi \times 2^3\right)$$
$$= 49966.5 \text{ mm}^3$$

Volume of pattern

$$V_p = (100 \times 1.03) \times (50 \times 1.03) \times (10 \times 1.03) - \frac{4}{3}\pi\,(2 \times 1.03)^3$$
$$= 54599.65 \text{ mm}^3$$

$$\therefore \frac{\text{Volume of pattern}}{\text{Volume of casting}} = V_p/V_s = (54599.65)/(49966.5)$$
$$= 1.09$$

Hence, the correct answer is 1.08 to 1.10.

Question Number: 60 **Question Type: NAT**

The voltage-length characteristic of a direct current arc in an arc welding process is $V = (100 + 40l)$, where l is the length of the arc in mm and V is the arc voltage in volts. During a welding operation, the arc length varies between 1 and 2 mm and the welding current is in the range 200–250 A. Assuming a linear power source, the short circuit current is ________ A.

Solution: Length l_1 = 1 mm,

Welding current I_1 = 250 A

Length l_2 = 2 mm,

Welding current I_2 = 200 A

Voltage V_1 = 140 V,

Voltage V_2 = 180 V

The voltage-length characteristic of a direct current arc in an arc welding process is

$$V = 100 + 40l$$

$$\frac{V}{V_{oc}} + \frac{I}{I_{sc}} = 1$$

$$V = V_{oc}\left(1 - \frac{I}{I_{sc}}\right)$$

We get,

$$140 = V_{oc}\left(1 - \frac{250}{I_{sc}}\right) \quad (1)$$

$$180 = V_{oc}\left(1 - \frac{200}{I_{sc}}\right) \quad (2)$$

On solving Eqs. (1) and (2), we get

$$0.777\left(1 - \frac{200}{I_{sc}}\right) = 1 - \frac{250}{I_{sc}}$$

$$I_{sc} = 424 \text{ A}$$

Hence, the correct answer is 423 to 428.

Question Number: 61 **Question Type: NAT**

For a certain job, the cost of metal cutting in Rs. 18C/V and the cost of tooling is Rs. 2701$C/(TV)$, where C is a constant, V is the cutting speed in m/min, and T is the tool life in minutes. The Taylor's tool life equation is $VT^{0.25}$ = 150. The cutting speed (in m/min) for the minimum total cost is ________.

Solution:

Taylor's tool life equation is $VT^{0.25} = 150$

Cost of metal cutting $C_t = \dfrac{18C}{V}$

Cost of tooling $C_m = \dfrac{270C}{TV}$

Let the cutting speed (in m/min) for the minimum total cost be V

$$\text{Total cost} = C_t + C_m$$

$$= \frac{18 \times 150}{V} + \frac{270 \times 150}{\dfrac{(150)^4}{V^4} \times V}$$

$$= \frac{2700}{V} + \left(8 \times 10^{-5}\right) V^3$$

Now we have

$$\frac{dC_{Total}}{dV} = 0$$

$$\frac{-2700}{V^2} + 3 \times 8 \times 10^{-5}\, V^2 = 0$$

$$V = 57.91 \text{ m/min}$$

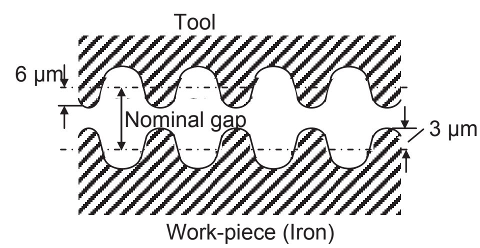
Hence, the correct answer is 57.8 to 58.

Question Number: 62 **Question Type: NAT**

The surface irregularities of electrodes used in an electro-chemical machining (ECM) process are 3 μm and 6 μm as shown in the figure. If the work-piece is of pure iron and 12V DC is applied between the electrodes, the largest feed rate is ________ mm/min.

Conductivity of the electrolyte	0.02 ohm^{-1} mm^{-1}
Over-potential voltage	1.5 V
Density of iron	7860 kg/m^3
Atomic weight of iron	55.85 gm

Assume the iron to be dissolved as Fe^{+2} and the Faraday constant to be 96,500 Coulomb.



Solution: Density of iron ρ = 7860 kg/m^3 = 7.86 g/cm^3

Conductivity of the electrolyte C = 0.02 ohm^{-1} mm^{-1} = 0.2 ohm^{-1} cm^{-1}

$$\text{Total gap } (y_c) = 3 \times 10^{-6} + 6 \times 10^{-6}$$
$$= 9 \times 10^{-6} \text{ m} = 9 \times 10^{-4} \text{ cm}$$

Over-potential voltage ΔV = 1.5V

Voltage applied between the electrodes V = 12V

Atomic weight of iron A = 55.85 gm

Z = 2, Faraday constant F = 96,500 Coulomb

Maximum feed rate can be calculated as

$$f_{max} = \frac{CA(V - \Delta V)}{\rho Z F\, y_e} \text{ m/s}$$

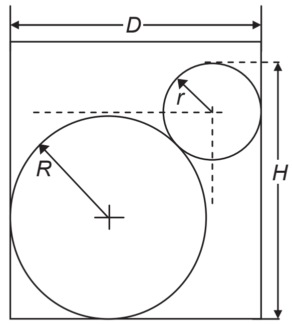
$$= \frac{0.2 \times 55.85 \times (12 - 1.5)}{7.86 \times 2 \times 96500 \times 9 \times 10^{-4}}$$

$$= 0.0852 \text{ cm/s} = 51.12 \text{ mm/min}$$

Hence, the correct answer is 51 to 52.

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

For the situation shown in the figure below, the expression for H in terms of r, R, and D is

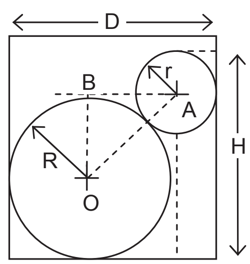


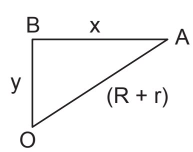
(A) $H = D + \sqrt{r^2 + R^2}$

(B) $H = (R + r) + (D + r)$

(C) $H = (R + r) + \sqrt{D^2 - R^2}$

(D) $H = (R + r) + \sqrt{2D(R+r) - D^2}$





Solution: From the above figure, we get

$$x = D - (R + r)$$

$$y = \sqrt{(R+r)^2 - (D-(R+r))^2}$$

$$= \sqrt{2D(R+r) - D^2}$$

Now we have

$$H = R + r + y$$

$$H = (R + r) + \sqrt{2D(R+r) - D^2}$$

Hence, the correct option is (D).

Question Number: 64 **Question Type: NAT**

A food processing company uses 25,000 kg of corn flour every year. The quantity-discount price of corn flour is provided in the table below:

Quantity (kg)	Unit price (Rs./kg)
1–749	70
750–1499	65
1500 and above	60

The order processing charges are Rs. 500/order. The handling plus carry-over charge on an annual basis is 20% of the purchase price of the corn flour per kg. The optimal order quantity (in kg) is _______.

Solution: Corn flour used every year D = 25,000 kg

Order processing charges C_o = Rs. 500/order

Handling plus carry-over charge on an annual basis i = 20% = 0.2

Now using the relation

$$EOQ = \sqrt{\frac{2DC_o}{C_u \times i}}$$

C_u is unit price

For C_u = Rs. 70/kg

$$(EOQ)_{70} = \sqrt{\frac{2 \times 25,000 \times 500}{70 \times 0.2}} = 1336.30 \text{ kg}$$

For C_u = Rs. 65/kg

$$(EOQ)_{65} = \sqrt{\frac{2 \times 25,000 \times 500}{65 \times 0.2}}$$

$$= 1386.75 \text{ kg}$$

For C_u = Rs.60 / kg

$$(EOQ)_{60} = \sqrt{\frac{2 \times 25,000 \times 500}{60 \times 0.2}} = 1443.37 \text{ kg}$$

On for C_u = Rs. 65, EOQ is lying within the given quantity band,

$$(TVC)_{65} = \sqrt{2DC_0C_ui} = \text{Rs. } 18,027.75$$

$$(TVC)_{60} = \left(\frac{D}{Q}\right)6 + \frac{Q}{2} \times (C_u i) = \text{Rs. } 17,333.33$$

where,

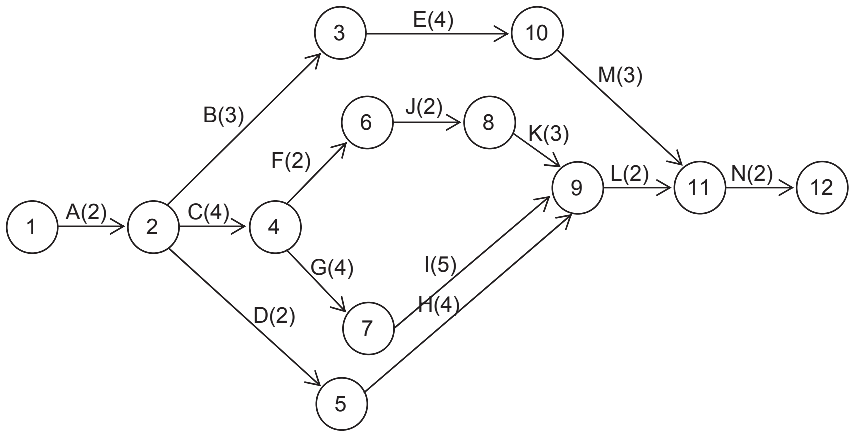
$$Q = 1500$$

$$(TVC)_{60} < (TVC)_{65}$$

$\therefore \qquad EOQ = 1500$

Hence, the correct answer is 1500.

Solution: Critical path is 1 – 2 – 4 – 7 – 9 – 11 – 12



Critical time = 19 days

Latest finish time for node 10 = 19 – (2 + 3) = 14 days

Hence, the correct answer is 14.

GATE 2016 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**

Based on the given statements, select the appropriate option with respect to grammar and usage.

Statements

(i) The height of Mr. **X** is 6 feet.
(ii) The height of Mr. **Y** is 5 feet.

(A) Mr. **X** is longer than Mr. **Y**.
(B) Mr. **X** is more elongated than Mr. **Y**.
(C) Mr. **X** is taller than Mr. **Y**.
(D) Mr. **X** is lengthier than Mr. **Y**.

Solution: 'tall' is used to denote the height of a person. As the comparison is made between the heights of two people, the comparative adjective 'taller' is correct to use here.

Hence, the correct option is (C).

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

The students ________ the teacher on teachers' day for twenty years of dedicated teaching.

(A) facilitated (B) felicitated
(C) fantasized (D) facillitated

Solution: 'Felicitated' means to compliment upon a happy event or to congratulate. The word facilitate is to aid or help. The word fantasize is envision or daydream.

Hence, the correct option is (B).

Question Number: 3 **Question Type: MCQ**

After India's cricket world cup victory in 1985, Shrotria who was playing both tennis and cricket till then, decided to concentrate only on cricket. And the <u>rest is history</u>.

What does the underlined phrase mean in this context?

(A) history will rest in peace
(B) rest is recorded in history books
(C) rest is well known
(D) rest is archaic

Solution: The correct option is (C).

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

Given (9 inches)$^{1/2}$ = (0.25 yards)$^{1/2}$, which one of the following statements is **TRUE**?

(A) 3 inches = 0.5 yards
(B) 9 inches = 1.5 yards
(C) 9 inches = 0.25 yards
(D) 81 inches = 0.0625 yards

Solution: $\left(9\,\text{inches}\right)^{1/2} = \left(0.25\text{ yards}\right)^{1/2}$ (1)

Squaring both sides, we get

9 inches = 0.25 yards.

Hence, the correct option is (C).

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

S, ***M***, ***E***, and ***F*** are working in shifts in a team to finish a project. ***M*** works with twice the efficiency of others but for half as many days as ***E*** worked. ***S*** and ***M*** have 6-hour shifts in a day, whereas ***E*** and ***F*** have 12-hour shifts. What is the ratio of contribution of ***M*** to contribution of ***E*** in the project?

(A) 1 : 1 (B) 1 : 2
(C) 1 : 4 (D) 2 : 1

Solution: Consider the table given below:

	S	*M*	*E*	*F*
Efficiency	1	2	1	1
Hours/day	6	6	12	12
Days		*n*	2*n*	

From the above data, the ratio of the work done by *M* and *E* is

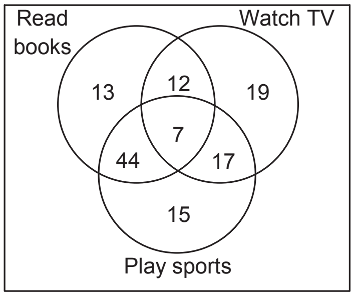
$$W_M/W_E = \frac{12n}{12(2n)} = \frac{1}{2}.$$

Hence, the correct option is (B).

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

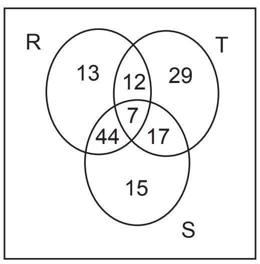
The Venn diagram shows the preference of the student population for leisure activities.

From the data given, the number of students who like to read books or play sports is ______.



(A) 44 (B) 51
(C) 79 (D) 108

Solution: Consider the Venn diagram given below:



The number of students who read books or play sports is $n(R \cup S)$

$$= (13 + 12 + 7 + 44) + (17 + 15)$$
$$= 76 + 32 = 108.$$

Hence, the correct option is (D).

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

Social science disciplines were in existence in an amorphous form until the colonial period when they were institutionalized. In varying degrees, they were intended to further the colonial interest. In the time of globalization and the economic rise of postcolonial countries like India, conventional ways of knowledge production have become obsolete.

Which of the following can be logically inferred from the above statements?

(i) Social science disciplines have become obsolete.
(ii) Social science disciplines had a pre-colonial origin.
(iii) Social science disciplines always promote colonialism.
(iv) Social science must maintain disciplinary boundaries.

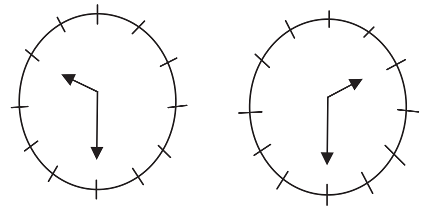
(A) (ii) only (B) (i) and (iii) only
(C) (ii) and (iv) only (D) (iii) and (iv) only

Solution: Hence options (i) and (iii) are incorrect. Statement (iv) is not stated. Statement (ii) can be understood from the first sentence of the passage.

Hence, the correct option is (A).

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

Two and a quarter hours back, when seen in a mirror, the reflection of a wall clock without number markings seemed to show 1:30. What is the actual current time shown by the clock?



(A) 8 : 15 (B) 11 : 15
(C) 12 : 15 (D) 12 : 45

Solution: Figure below shows the actual positions of the hands of the clock and the reflection

The actual time, two and a quarter hours back, was 10:30. Now it is 12:45.

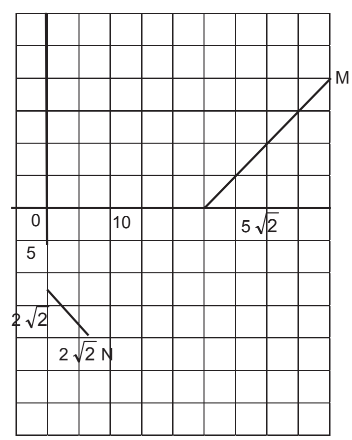
Hence, the correct option is (D).

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

M and *N* start from the same location. *M* travels 10 km East and then 10 km North-East. *N* travels 5 km South and then 4 km South-East. What is the shortest distance (in km) between *M* and *N* at the end of their travel?

(A) 18.60 (B) 22.50
(C) 20.61 (D) 25.00

Solution:



The starting point for both M and N is 0, the origin. The final positions are

$M = \left(10+5\sqrt{2}, 5\sqrt{2}\right)$ and $N = \left(2\sqrt{2}, -5-2\sqrt{2}\right)$

$$\therefore \quad MN^2 = \left(10+3\sqrt{2}\right)^2 + \left(5+7\sqrt{2}\right)^2$$

$$= \left(118+60\sqrt{2}\right)+\left(123+70\sqrt{2}\right)$$

$$= 241 + 130\sqrt{2}$$

$$\Rightarrow \quad MN = 20.61.$$

Hence, the correct option is (C).

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

A wire of length 340 mm is to be cut into two parts. One of the parts is to be made into a square and the other into a rectangle where sides are in the ratio of 1 : 2. What is the length of the side of the square (in mm) such that the combined area of the square and the rectangle is a **MINIMUM**?

(A) 30 (B) 40
(C) 120 (D) 180

Solution: Length of the wire = 340 m

If the side of the square be a, let the breadth and length of the rectangle be b and $2b$, respectively.

$$4a + 2(b + 2b) = 340$$

$$2a + 3b = 170$$

We need the value of a for which $y = a^2 + 2b^2$ has the minimum possible value

$$y = a^2 + 2\left(\frac{170-2a}{3}\right)^2$$

$$\Rightarrow \quad 9y = 9a^2 + 8\,(85 - a)^2 \qquad (1)$$

$$9y = 17a^2 - 8(17a) + 8(85)^2$$

$$\therefore \quad \frac{d}{da}(9y) = 34a - 8(170) = 0$$

$$\Rightarrow \quad a = 40$$

Form Eq. (1), we conclude that the graph of $9y$ vesus a is a parabola and y has the minimum value at $a = 40$.

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**

A real square matrix A is called skew-symmetric if

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

Solution: A real square matrix A is called skew-symmetric if $A^T = -A$

Hence, the correct option is (C).

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

$\underset{x\to 0}{\text{Lt}} \dfrac{\log_e(1+4x)}{e^{3x}-1}$ is equal to

(A) 0 (B) $\frac{1}{2}$
(C) $\frac{4}{3}$ (D) 1

Solution:

$$\underset{x\to 0}{Lt}\frac{\log_e(1+4x)}{e^{3x}-1} = \underset{x\to 0}{Lt}\frac{\left(\dfrac{4}{1+4x}\right)}{3e^{3x}}$$

(By using L'Hospital's rule)

$$= \frac{4}{3}$$

Hence, the correct option is (C).

Question Number: 13 **Question Type: MCQ**

Solutions of Laplace's equation having continuous second-order partial derivatives are called

(A) biharmonic functions
(B) harmonic functions
(C) conjugate harmonic functions
(D) error functions

Solution: Solutions of Laplace's equation having continuous second-order partial derivatives are called harmonic functions.

Hence, the correct option is (B).

Question Number: 14 **Question Type: NAT**

The area (in percentage) under standard normal distribution curve of random variable Z within limits from –3 to +3 is _______.

Solution: The area (in percentage) under standard normal distribution curve of random variable Z within limits from –3 to +3 is 99.74.

Hence, the correct answer is 99.74.

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

The root of the function $f(x) = x^3 + x - 1$ obtained after the first iteration on application of Newton-Raphson scheme suing an initial guess of $x_0 = 1$ is

(A) 0.682 (B) 0.686
(C) 0.750 (D) 1.000

Solution: The given function is

$$f(x) = x^3 + x - 1$$

Derivative of the function will be

$$F'(x) = 3x^2 + 1$$

At $x_0 = 1$, the function and its derivative will be $f(x_0) = f(1) = 1$ and $f'(x_0) = f'(1) = 4$

By Newton-Raphson method,

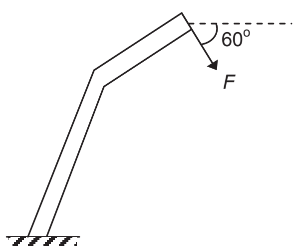
$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

$$= 1 - \frac{1}{4} = 0.75$$

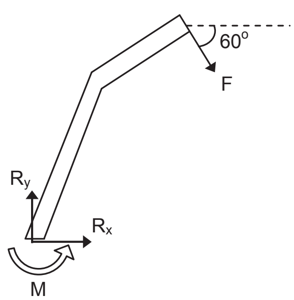
Hence, the correct option is (C).

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

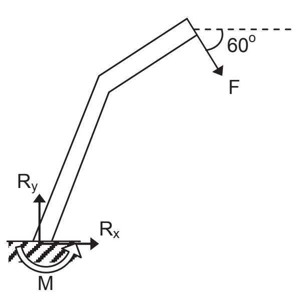
A force F is acting on a bent bar which is clamped at one end as shown in the figure.



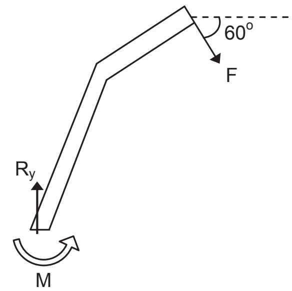
The CORRECT free-body diagram is



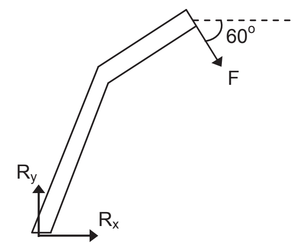
(A)



(B)

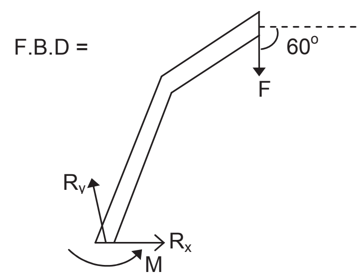


(C)



(D)

Solution: The required free-body diagram is given below:

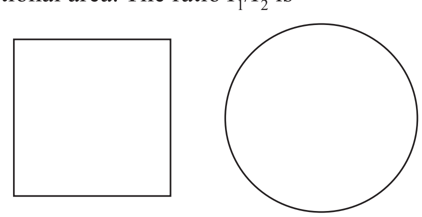


All supports have to be isolated in F.B.D.

Hence, the correct option is (A).

Question Number: 17 **Question Type: MCQ**

7.The cross-sections of two solid bars made of the same material are shown in the figure. The square cross-section has flexural (bending) rigidity I_1, while the circular cross-section has flexural rigidity I_2. Both sections have the same cross-sectional area. The ratio I_1/I_2 is



(A) $1/\pi$ (B) $2/\pi$
(C) $\pi/3$ (D) $\pi/6$

Solution: Let the side of square be a cm and circular diameter be d cm.

Now area of square = a^2

and area of circle $= \frac{\pi}{4} d^2$

Since square and circle have equal areas

$$a^2 = \frac{\pi}{4} d^2$$

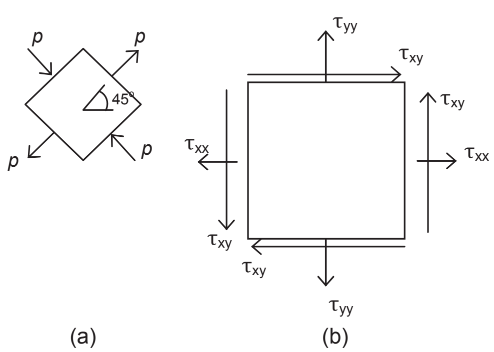
Now using the relation

$$\frac{I_1}{I_2} = \frac{a^4}{12 \times \frac{\pi d^4}{64}} = \frac{64}{12\pi} \times \frac{\pi^2}{16} = \frac{\pi}{3}$$

Hence, the correct option is (C).

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

The state of stress at a point on an element is shown in figure (a). The same state of stress is shown in another coordinate system in figure (b).

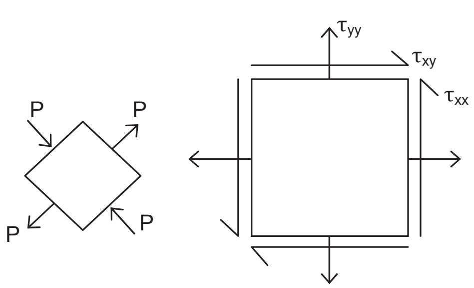


The components (τ_{xx}, τ_{yy}, τ_{xy}) are given by

(A) $\left(p/\sqrt{2}, -p/\sqrt{2}, 0\right)$ (B) (0, 0, p)

(C) $\left(p, -p, p/\sqrt{2}\right)$ (D) $\left(0, 0, p/\sqrt{2}\right)$

Solution:

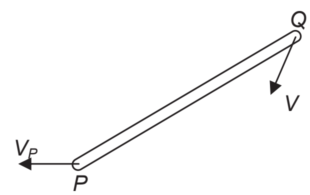


Given principal stresses are equal and opposite and are acting at a plane inclined at $\theta = 45^{\circ}$ with respect to x-axis. Which is a pure shear state of stress? So, $\tau_{xy} = p$, $\tau_{yy} = \tau_{xx} = 0$.

Hence, the correct option is (B).

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

A rigid link PQ is undergoing plane motion as shown in the figure (V_P and V_Q are non-zero). V_{QP} is the relative velocity of point Q with respect to point P.



Which one of the following is TRUE?

(A) V_{QP} has components along and perpendicular to PQ.
(B) V_{QP} has only one component directed from P to Q.
(C) V_{QP} has only one component directed from Q to P.
(D) V_{QP} has only one component perpendicular to PQ.

Solution: V_{QP} will have one component perpendicular to PQ.

Hence, the correct option is (D).

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

The number of degrees of freedom in a planer having n links and j simple hinge joints is

(A) $3(n – 3) – 2j$ (B) $3(n – 1) – 2j$
(C) $3n – 2j$ (D) $2j – 3n + 4$

Solution: The number of degrees of freedom in a planer having n links and j simple hinge joints is $3(n – 1) – 2j$.

Hence, the correct option is (B).

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

The static deflection of a spring under gravity, when a mass of 1 kg is suspended from it, is 1 mm. Assume the acceleration due to gravity g = 10 m/s^2. The natural frequency of this spring-mass system (in rad/s) is ______.

Solution: Mass m = 1 kg

Static deflection of spring δ = 1 mm

Acceleration due to gravity g = 10 m/s^2

Let the natural frequency of this spring-mass system ω_n = ?

Now using the relation

$$\omega_n = \sqrt{g/\delta} = \sqrt{\frac{10}{1 \times 10^{-3}}} = 100 \text{ rad/s.}$$

Hence, the correct answer is 100.

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

Which of the bearings given below SHOULD NOT be subjected to a thrust load?

(A) Deep groove ball bearing
(B) Angular contact ball bearing
(C) Cylindrical (straight) roller bearing
(D) Single row tapered roller bearing

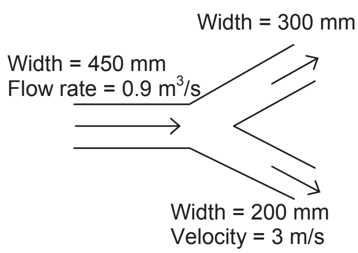
Solution: Cylindrical roller bearing should not be subjected to thrust loads.

Hence, the correct option is (C).

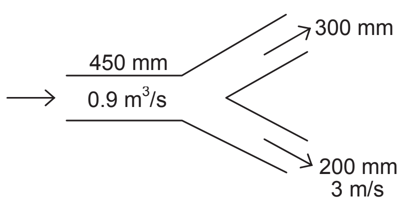
Question Number: 23 **Question Type: NAT**

A channel of width 450 mm branches into two sub-channels having width 300 mm and 200 mm as shown in the figure. If the volumetric flow rate (taking unit depth) of an incompressible flow through the main channel is 0.9 m^3/s and the velocity in the sub-channel of width 200 mm is 3 m/s, the velocity in the sub-channel of width 300 mm is ______ m/s.

Assume both inlet and outlet to be at the same elevation.



Solution:



From the above figure, equating mass flow rate, we get

$$0.9 = 0.3V + 0.2 \times 3$$
$$0.9 = 0.3V + 0.6$$
$$0.3V = 0.3$$
$$V = 1 \text{ m/s}$$

Hence, the correct answer is 1.

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

For a certain two-dimensional incompressible flow, velocity field is given by $2xy\hat{i} - y^2\hat{j}$. The streamlines for this flow are given by the family of curves

(A) x^2y^2 = constant (B) xy^2 = constant
(C) $2xy - y^2$ = constant (D) xy = constant

Solution: Given that velocity field is $\overline{V} = 2xy\hat{i} - y^2\hat{j}$

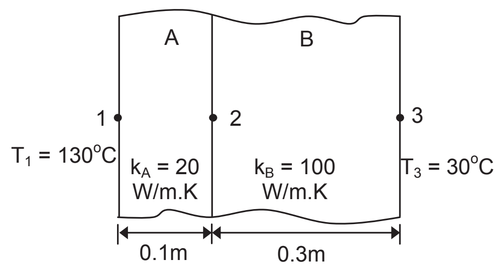
$\Psi = ?$

$$-u = \frac{\delta\psi}{\delta y},\ V = -\frac{\delta\psi}{\delta x}$$
$$-2xy\,dy = d\Psi$$
$$\Psi = -xy^2 + F(x)$$
$$\frac{\delta\psi}{\delta x} = f'(x) - y^2$$
$$F'(x) = 0 \Rightarrow F(x) = \text{Constant}$$
$$\Rightarrow \quad \Psi = xy^2 = \text{constant.}$$

Hence, the correct option is (B).

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

Steady one-dimensional heat conduction takes place across the faces 1 and 3 of a composite slab consisting of slabs A and B in perfect contact as shown in the figure, where k_A, k_B denote the respective thermal conductivities. Using the data given in the figure, the interface temperature T_2 (in °C) is _________.



Solution: Now using the relation

$$Q_{13} = Q_{12} = Q_{23}$$
$$\frac{130 - 30}{\frac{0.1}{20} + \frac{0.3}{100}} = \frac{130 - T_2}{\frac{0.1}{20}}$$
$$\Rightarrow \quad T_2 = 67.5^\circ\text{C}$$

Hence, the correct answer is 67.5.

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

Grash of number signifies the ratio of

(A) inertia force to viscous force
(B) buoyancy force to viscous force
(C) buoyancy force to inertia force
(D) inertia force to surface tension force

Solution: Grashof number is the ratio of buoyancy force to viscous force and is expressed as

$$G_r = \frac{g\beta\Delta T L^3}{\upsilon^2}.$$

Hence, the correct option is (B).

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

The INCORRECT statement about the characteristics of critical point of a pure substance is that

(A) there is no constant temperature vaporization process
(B) it has point of inflection with zero slope
(C) the ice directly converts from solid phase to vapor phase
(D) saturated liquid and saturated vapor states are identical

Solution: The ice directly converts from solid phase to vapor phase, this statement is false. Critical point is used to specifically denote the vapor–liquid critical point of a material, above which distinct liquid and gas phases do not exist.

Hence, the correct option is (C).

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

For a heat exchanger, ΔT_{max} is the maximum temperature difference and ΔT_{min} is the minimum temperature difference between the two fluids. *LMTD* is the log mean temperature difference. C_{min} and C_{max} are the minimum and the maximum heat capacity rates. The maximum possible heat transfer (Q_{max}) between the two fluids is

(A) $C_{min}\ LMTD$ (B) $C_{min}\ \Delta T_{max}$
(C) $C_{max}\ \Delta T_{max}$ (D) $C_{max}\ \Delta T_{min}$

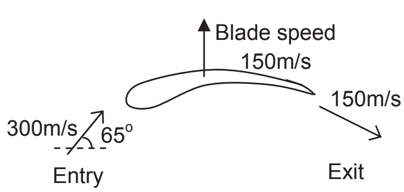
Solution: The maximum possible heat transfer (Q_{max}) between the two fluids is

$$Q_{max} = (\Delta T)_{max}\ C_{min}.$$

Hence, the correct option is (B).

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

The blade and fluid velocities for an axial turbine are as shown in the figure.

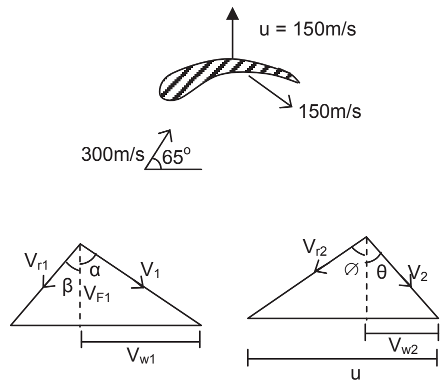


The magnitude of absolute velocity at entry is 300 m/s at an angle of 65° to the axial direction, while the magnitude of the absolute velocity at exit is 150 m/s. The exit velocity vector has a component in the downward direction. Given that the axial (horizontal) velocity is the same at entry and exit, the specific work (in kJ/kg) is ______.

Solution: Entry angle $\alpha = 65°$,

Absolute u = 150 m/s

Magnitude of the absolute velocity at entry V_1 = 300 m/s,



Magnitude of the absolute velocity at exit V_2 = 150 m/s

We know that

$$V_{F_1} = V_{F_2}$$
$$V_1 \cos\alpha = V_2 \cos\theta$$
$$300 \cos 65 = 150 \cos\theta$$
$$\theta = 32.3°$$

Now

$$V_{\omega_1} = V_1 \sin\alpha = 300 \sin 65 = 272 \text{ m/s}$$
$$V_{\omega_2} = V_2 \sin\theta = 150 \sin 32.3 = 80.15 \text{ m/s}$$

The specific work (in kJ/kg)

$$W = \left(V_{\omega_1} + V_{\omega_2}\right)u$$
$$= (272 + 80.15)150 = 52.82 \text{ kJ/kg}$$

Hence, the correct answer is 50 – 54.

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

Engineering strain of a mild steel sample is recorded as 0.100%. The true strain is

(A) 0.010% (B) 0.055%
(C) 0.099% (D) 0.101%

Solution:

Engineering strain $e = 0.1\% = \frac{0.1}{100}$

True strain ε_T = ?

The true strain can be calculated using

$$\varepsilon_T = \ln(1 + e) = \ln(1 + 0.001) = \ln(1.001)$$
$$= 9.99 \times 10^{-4} = 9.99 \times 10^{-2}\% = 0.099\%$$

Hence, the correct option is (C).

Question Number: 31 **Question Type: MCQ**

Equal amounts of a liquid metal at the same temperature are poured into three moulds made of steel, copper, and aluminum. The shape of the cavity is a cylinder with 15 mm diameter. The sizes of the moulds are such that the outside temperatures of the moulds do not increase appreciably beyond the atmospheric temperature during solidification. The sequence of solidification in the mould from the fastest to slowest is

(Thermal conductivities of steel, copper, and aluminum are 60.5, 401, and 237 W/m-K, respectively Specific heats of steel, copper, and aluminum are 434, 385, and 903 J/kg-K, respectively. Densities of steel, copper, and aluminum are 7854, 8933, and 2700 kg/m^3, respectively.)

(A) Copper – Steel - Aluminum
(B) Aluminum – Steel – Copper
(C) Copper – Aluminum – Steel
(D) Steel – Copper – Aluminum

Solution: Thermal diffusivity $\alpha = \dfrac{k}{\rho C}$

Thermal conductivity is k

Density = ρ

Specific heat = C

For copper

$$\alpha_{\text{copper}} = \left(\frac{k}{\rho C}\right)_{\text{copper}} = \frac{401}{3439} \times 10^{-3}$$

$$\approx 0.1166 \times 10^{-3} \text{ m}^2/\text{s}$$

For steel

$$\alpha_{\text{steel}} = \left(\frac{k}{\rho C}\right)_{\text{steel}} = \frac{60.5 \times 10^{-3}}{3400}$$

$$\approx 0.0177 \times 10^{-3} \text{ m}^2/\text{s}$$

For aluminum

$$\alpha_{\text{aluminum}} = \left(\frac{k}{\rho C}\right)_{\text{aluminum}}$$

$$= \frac{237}{2430} \times 10^{-3}$$

$$\approx 0.1119 \times 10^{-3} \text{ m}^2/\text{s}$$

Hence, the correct option is (C).

Question Number: 32 **Question Type: MCQ**

In a wire-cut EDM process, the necessary conditions that have to be met for making a successful cut are that

(A) wire and sample are electrically non-conducting
(B) wire and sample are electrically conducting
(C) wire is electrically conducting and sample is electrically non-conducting
(D) sample is electrically conducting and wire is electrically non-conducting

Solution: The correct option is (B).

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

Internal gears are manufactured by

(A) hobbing
(B) shaping with pinion cutter
(C) shaping with rack cutter
(D) milling

Solution: Internal gears are manufactured by shaping with pinion cutter.

Hence, the correct option is (B).

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

Match the following part programming codes with their respective functions.

Part programming codes	Functions
P. G01	I. Spindle stop
Q. G03	II. Spindle rotation, clockwise
R. M03	III. Circular interpolation, anticlockwise
S. M05	IV. Linear interpolation

(A) P – II, Q – I, R – IV, S – III
(B) P – IV, Q – II, R – III, S – I
(C) P – IV, Q – III, R – II, S – I
(D) P – III, Q – IV, R – II, S – I

Solution: G01 – linear interpolation, G03 – circular interpolation, ACW.

M03 – spindle rotation, CW; M05 – spindle stop.

Hence, the correct option is (C).

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

In PERT chart, the activity time distribution is

(A) Normal (B) Binormal
(C) Poisson (D) Beta

Solution: In Pert activity, time distribution is Beta distribution.

Hence, the correct option is (D).

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

The number of linearly independent eigenvectors of matrix $A = \begin{bmatrix} 2 & 1 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$ is ________.

Solution:

Given matrix is $A = \begin{bmatrix} 2 & 1 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$

The eigen values of A are 2, 2, and 3.

Let $X_1 = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ be an eigen vector of A corresponding to the eigen value $\lambda = 2$

$$\therefore \quad (A - \lambda I) X_1 = 0$$

$$\Rightarrow (A - 2I) X_1 = 0$$

$$\Rightarrow \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\Rightarrow \qquad x_2 = 0$$

$$x_3 = 0$$

and x_1 can be arbitrary.

Let $x_1 = k$, where k is arbitrary.

The eigen vector of A corresponding to the eigen value $\lambda = 2$ is $X_1 = \begin{bmatrix} k \\ 0 \\ 0 \end{bmatrix} = k \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$

i.e., only one arbitrary value occurred in the eigen vector of A corresponding to the eigen value that is repeated. From this, one can conclude that the total number of linearly independent eigen vectors of A is 2.

Hence, the correct answer is 02.

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

The value of the line integral $\oint_C \bar{F} \cdot \bar{r}' ds$, where C is a circle of radius $\frac{4}{\sqrt{\pi}}$ units is ______.

Here, $\bar{F}(x, y) = y\hat{i} + 2x\hat{j}$ and $\bar{r}'$ is the **UNIT** tangent vector on the curve C at an arc length s from a reference point on the curve. $\hat{i}$ and $\hat{j}$ are the basis vectors in the x-y Cartesian reference. In evaluating the line integral, the curve has to be traversed in the counter-clockwise direction.

Solution: We have to evaluate $\oint_C \bar{F} \cdot \bar{r}\, ds$

where C is a circle with radius $\frac{4}{\sqrt{\pi}}$

and $\qquad \bar{F} = y\bar{i} + 2x\bar{j}$

$$\oint_C \bar{F} \cdot \bar{r} ds = \oint_C \left[y\bar{i} + 2x\bar{j} \right] \cdot \left[dx\bar{i} + dyj \right]$$

$$= \oint_C \left[ydx + 2xdy \right]$$

$$= \iint_R \left[\frac{\partial(2x)}{\partial x} - \frac{\partial(y)}{\partial y} \right] dxdy$$

(By Green's theorem)

where R is the region of the circle C.

$$= \iint_R [2-1] dxdy$$

$$= \iint_R [2-1] dxdy$$

$$= \text{Area of the circle } C \left(= \pi r^2 \right)$$

$$= \pi \left(\frac{4}{\sqrt{\pi}} \right)^2 = 16$$

Hence, the correct answer is 16.

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

$\lim_{x \to \infty} \sqrt{x^2 + x - 1} - x$ is

(A) 0 (B) ∞
(C) 1/2 (D) $-\infty$

Solution: We have $\lim_{x \to \infty} \sqrt{x^2 + x - 1} - x$

$$= \lim_{x \to \infty} \left[\sqrt{x^2 + x - 1} - x \right] \times \frac{\left[\sqrt{x^2 + x - 1} + x \right]}{\left[\sqrt{x^2 + x - 1} + x \right]}$$

$$= \lim_{x \to \infty} \frac{\left(x^2 + x - 1 \right) - x^2}{\left[\sqrt{x^2 + x - 1} + x \right]}$$

$$= \lim_{x \to \infty} \frac{x - 1}{\left[\sqrt{x^2 \left(1 + \frac{1}{x} - \frac{1}{x^2} \right)} + x \right]}$$

$$= \lim_{x \to \infty} \frac{x \left(1 - \frac{1}{x} \right)}{\left[x \left[\sqrt{\left(1 + \frac{1}{x} - \frac{1}{x^2} \right)} \right] + 1 \right]}$$

$$= \lim_{x \to \infty} \frac{1 - \frac{1}{x}}{\left[\sqrt{1 + \frac{1}{x} - \frac{1}{x^2}} + 1 \right]} = \frac{1}{2}$$

Hence, the correct option is (C).

Question Number: 39 **Question Type: MCQ**

Three cards were drawn from a pack of 52 cards. The probability that they are a king, a queen, and a jack is

(A) $\frac{16}{5525}$ (B) $\frac{64}{2197}$

(C) $\frac{3}{13}$ (D) $\frac{8}{16575}$

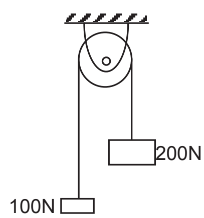
Solution: When three cards were drawn from a pack of 52 cards, the probability that they are a king, a queen, and a jack

$$= \frac{{}^4C_1 \times {}^4C_1 \times {}^4C_1}{{}^{52}C_3} = \frac{16}{5525}$$

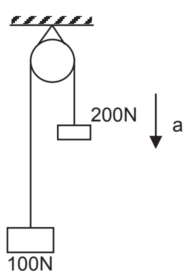
Hence, the correct option is (A).

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

An inextensible mass less string goes over a frictionless pulley. Two weights of 100 N and 200 N are attached to the two ends of the string. The weights are released from rest, and start moving due to the gravity. The tension in the string (in N) is _______.



Solution:



If a is the acceleration of system, g is the acceleration due to gravity, and T be the tension, then we have

$$T - 200 = \frac{200}{g}a \quad (1)$$

$$T - 100 = -\frac{100}{g}a \quad (2)$$

Solving Eqs. (1) and (2), we have

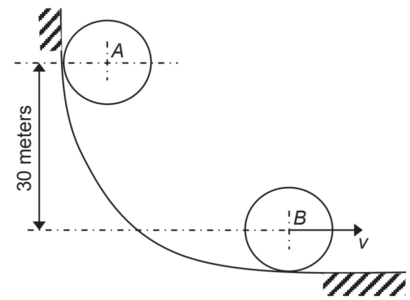
$$T = 133.33 \text{ N}$$

Hence, the correct answer is 133 – 134.

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

A circular disc of radius 100 mm and mass 1 kg, initially at rest at position A, rolls without slipping down a curved path as shown in the figure. The speed v of the disc when it reaches position B is _______ m/s.

Acceleration due to gravity g = 10 m/s².

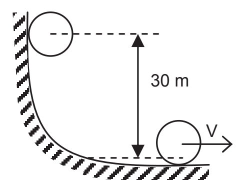


Solution: Radius of circular disc r = 100 m

Mass m = 1 kg

Speed of the disc v?

Applying conservation of energy,



Now we get

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}(I_o)\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{1}{2}mr^2\omega^2$$

$$= \left(\frac{1}{2} + \frac{1}{4}\right)mv^2 = \frac{3}{4}mv^2$$

$$v = \sqrt{\frac{4gh}{3}}$$

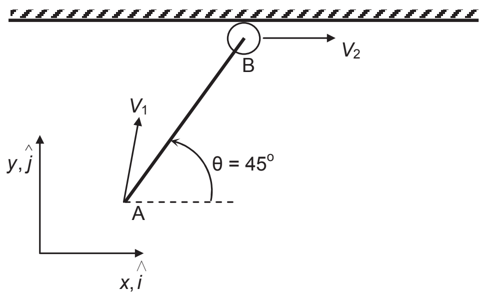
$$v = 20 \text{ m/s}$$

Hence, the correct answer is 20.

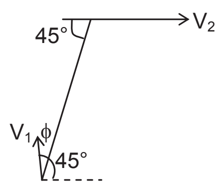
Question Number: 42 **Question Type: NAT**

A rigid rod (AB) of length $L = \sqrt{2}$ m is undergoing translational as well as rotational motion in the x-y plane (see the figure). The point A has the velocity $V_1 = \hat{i} + 2\hat{j}$ m/s. The end B is constrained to move only along the x direction.

The magnitude of the velocity V_2 (in m/s) at the end B is ______.



Solution:



Velocity at point A is $V_1 = \hat{i} + 2\hat{j}$ m/s.

Magnitude of velocity at point A

$V_1 = \sqrt{1+4} = \sqrt{5}$ m/s

V_1 makes an angle $\tan^{-1}(2)$ or 63.43° with x-axis.

$\therefore \quad \phi = 63.43° - 45°$

$= 18.43°$

Let the velocity at point B be V_2=?

For rod AB to be rigid,

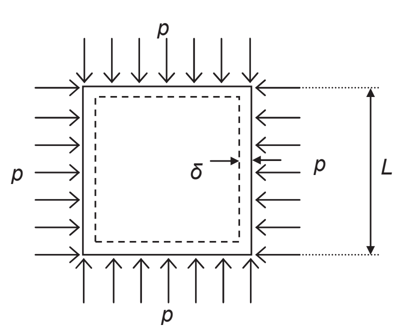
$$V_1 \cos \phi = V_2 \cos 45°$$

$$V_2 = 3 \text{ m/s}$$

Hence, the correct answer is 3.

Question Number: 43 **Question Type: NAT**

A square plate of dimension $L \times L$ is subjected to a uniform pressure load p = 250 MPa on its edges as shown in the figure. Assume plane stress conditions. The Young's modulus E = 200 GPa.



The deformed shape is a square of dimension $L - 2\delta$. If L = 2 m and δ = 0.001 m, the Poisson's ratio of the plate material is ______.

Solution:

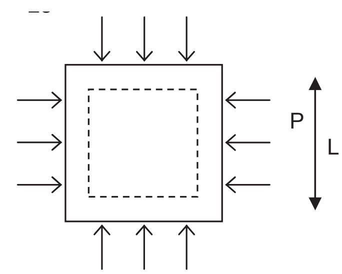
Uniform pressure P = 250 MPa

δ = 0.001 m

Young's modulus E = 200 GPa

Length L = 2 m

$\varepsilon_x = 28$



$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\mu \sigma_y}{\in} \Rightarrow \frac{1}{E}[\sigma_x - \mu\,\sigma_y]$$

$$\frac{2 \times 0.001}{2} = \frac{1}{200 \times 10^9} \times 250 \times 10^6 \,[1-\mu]$$

$$0.8 = 1 - \mu \Rightarrow \mu = 0.2$$

Hence, the correct answer is 0.2.

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

Two circular shafts made of the same material, one solid (S) and one hollow (H), have the same length and polar moment of inertia. Both are subjected to same torque. Here, θ_S is the twist and τ_S is the maximum shear stress in the solid shaft, whereas θ_H is the twist and τ_H is the maximum shear stress in the hollow shaft. Which one of the following is TRUE?

(A) $\theta_S = \theta_H$ and $\tau_S = \tau_H$ (B) $\theta_S > \theta_H$ and $\tau_S > \tau_H$

(C) $\theta_S < \theta_H$ and $\tau_S < \tau_H$ (D) $\theta_S = \theta_H$ and $\tau_S < \tau_H$

Solution: $\text{Material}_{\text{hollow}} = \text{Material}_{\text{solid}}$

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$$

$\Rightarrow \quad \tau \propto r$

$\because \quad r_H > r_S$

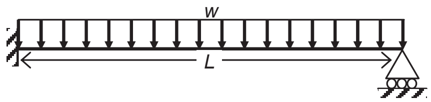
$\Rightarrow \quad \tau_H > \tau_S$

$$\theta_{\text{solid}} = \theta_{\text{hollow}}$$

Hence, the correct option is (D).

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

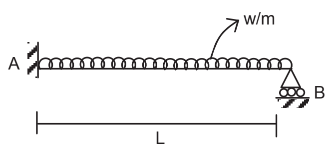
A beam of length L is carrying a uniformly distributed load w per unit length. The flexural rigidity of the beam is EI. The reaction at the simple support at the right end is



(A) $\frac{wL}{2}$ (B) $\frac{3wL}{8}$

(C) $\frac{wL}{4}$ (D) $\frac{wL}{8}$

Solution:



Let R_B be reaction at B.

Deflection due to U.D.L $= \frac{\omega L^4}{8EI}$ (1)

Upward deflection due to simple support at

$$B = \frac{R_B L^3}{3EI} \quad (2)$$

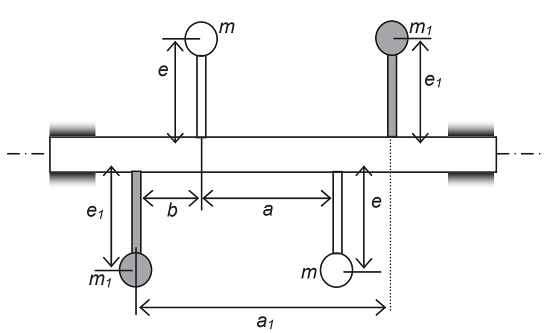
From Eqs. (1) and (2), we get

We have $R_B = \frac{3}{8}wL$.

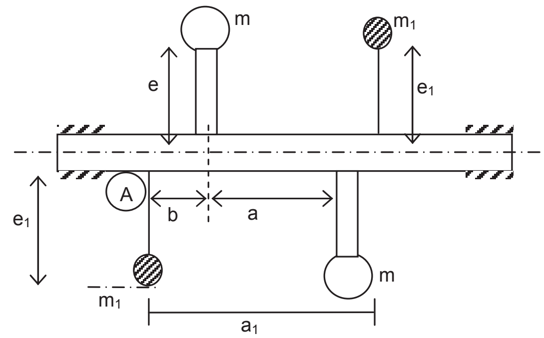
Hence, the correct option is (B).

Question Number:46 **Question Type: NAT**

Two masses m are attached to opposite sides of a rigid rotating shaft in the vertical plane. Another pair of equal masses m_1 is attached to the opposite sides of the shaft in the vertical plane as shown in the figure. Consider $m = 1$ kg, $e = 50$ mm, $e_1 = 20$ mm, $b = 0.3$ m, $a = 2$ m, and $a_1 = 2.5$ m. For the system to be dynamically balanced, m_1 should be ________ kg.



Solution:



Mass $m = 1$ kg,

Distance $e = 50$ mm,

Distance $e_1 = 20$ mm,

Length $b = 0.3$ m,

Length $a = 2$ m,

Length $a_1 = 2.5$ m,

Mass $m_1 = ?$

We know that couple on any plane should be zero for dynamic balance

$$M_A = 0$$

$$\Rightarrow \quad meb + m_1 e_1 a_1 = m(a + b)e$$

$$\Rightarrow \quad m_1 e_1 a_1 = m\, e\, a$$

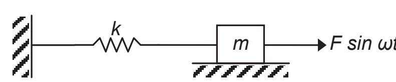
$$m_1 = \frac{1 \times 50 \times 2}{20 \times 2.5} = 2$$

$$m_1 = 2 \text{ kg}$$

Hence, the correct answer is 2.

Question Number: 47 **Question Type: NAT**

A single degree of freedom spring-mass is subjected to a harmonic force of constant amplitude. For an excitation frequency of $\sqrt{\frac{3k}{m}}$, the ratio of the amplitude of steady-state response to the static deflection of the spring is ___________.



Solution: Excitation frequency $\omega = \sqrt{\frac{3k}{m}}$

Also, we have $\omega_n = \sqrt{\frac{k}{m}}$

Magnification factor can be calculated as

$$= \frac{1}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

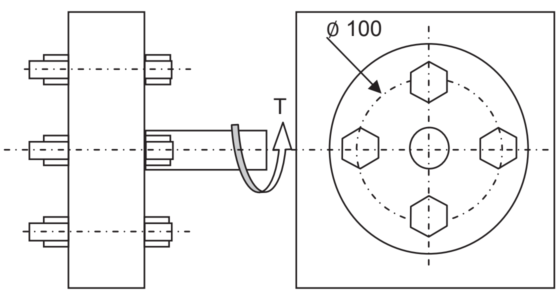
$$= \pm\frac{1}{1-\left(\frac{\omega}{\omega_n}\right)^2} = \pm\frac{1}{1-3} = \frac{1}{2}$$

(Neglecting –ve sign)

Hence, the correct answer is 0.5.

Question Number: 48 **Question Type: NAT**

A bolted joint has four bolts arranged as shown in the figure. The cross-sectional area of each bolt is 25 mm^2. A torque T = 200 N-m is acting on the joint. Neglecting friction due to clamping force, the maximum shear stress in a bolt is _________ MPa.



Solution: Torque T = 200 N-m

Cross-sectional area of each bolt A = 25 mm^2

Number of bolts n = 4

Now using the relation

$$T = n \times A \times \tau_{max} \times \frac{PCD}{2}$$

$$200 \times 10^3 = 4 \times 25 \times \frac{100}{2} \times \tau_{max}$$

Maximum torque will be

$$\tau_{max} = \frac{200\times10^3\times4\times2}{25\times100} = 40 \text{ N/mm}^2$$

Hence, the correct answer is 40.

Question Number: 49 **Question Type: NAT**

Consider a fully developed steady laminar flow of an incompressible fluid with viscosity μ through a circular pipe of radius R. Given that the velocity at a radial location of $R/2$ from the centerline of the pipe is U_1, the shear stress at the wall is $K\mu U_1/R$, where K is ________.

Solution:

As per problem, $U_{R/2} = U_1$

Also $\tau_{wall} = k\,\mu\, u_1/R$

$$u = u_{max}\left(1-\frac{r^2}{R^2}\right)$$

$$U_1 = \frac{3}{4}\; u_{max}$$

$$\tau_{wall} = \mu\frac{du}{dr} = \mu\, u_{max}\;\frac{2r}{R^2}$$

$$= 2\,\mu\frac{u_{max}}{R} = 2\frac{\mu}{R}\times\frac{4}{3}u_1$$

$$= \frac{8}{3}\mu\frac{u_1}{R}$$

$\therefore$ $k = \frac{8}{3} = 2.667$

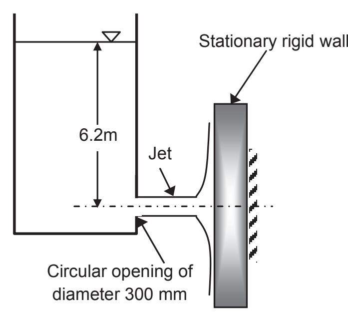
Hence, the correct answer is 2.6 – 2.7.

Question Number: 50 **Question Type: NAT**

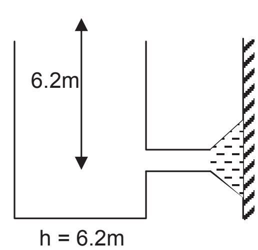
The water jet exiting from a stationary tank through a circular opening of diameter 300 mm impinges on a rigid wall as shown in the figure. Neglect all minor losses and assume the water level in the rank to remain constant. The net horizontal force experienced by the wall is _________ kN.

Density of water is 1000 kg/m^3.

Acceleration due to gravity g = 10 m/s2.



Solution:



Force exerted by a set of water striking fixed wall is

$$= \rho a v^2 = 10^3 \times \frac{\pi}{4} \times 0.3^2 \times V^2$$

Height $h = 6.2$ m

Velocity of jet can be calculated as

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

$$= 10^3 \times \frac{\pi}{4} \times 0.3^2 \times 2 \times 10 \times 6.2 = 8.76 \text{ kN}$$

Hence, the correct answer is 8.7 – 8.8.

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

For a two-dimensional flow, the velocity field is $\vec{u} = \frac{x}{x^2+y^2}\hat{i} + \frac{y}{x^2+y^2}\hat{j}$, where $\hat{i}$ and $\hat{j}$ are the basis vectors in the *x*-*y* Cartesian coordinate system. Identify the **CORRECT** statements from the following.

(1) The flow is incompressible.

(2) The flow is unsteady.

(3) *y*-component of acceleration,

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

(4) *x*-component of acceleration,

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

(A) (2) and (3) (B) (1) and (3)
(C) (1) and (2) (D) (3) and (4)

Solution:

$$u = \frac{x}{x^2+y^2} \qquad V = \frac{y}{x^2+y^2}$$

$$a_x = \frac{u\delta u}{\delta x} + V\frac{\delta u}{\delta y}$$

$$\frac{\delta u}{\delta x} = \frac{y^2-x^2}{\left(x^2+y^2\right)^2}, \quad \frac{\delta v}{\delta y} = \frac{x^2-y^2}{(x^2+y^2)^2}$$

$$\frac{\delta u}{\delta y} = \frac{-2xy}{\left(x^2+y^2\right)^2}$$

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

also, $$\frac{\delta u}{\delta x} + \frac{\delta v}{\delta y} = 0$$

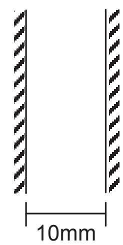
Flow is steady and incompressible.

Hence, the correct option is (B).

Question Number: 52 **Question Type: NAT**

Two large parallel plates having a gap of 10 mm in between them are maintained at temperatures T_1 = 1000 K and T_2 = 400 K. Given emissivity values, $\varepsilon_1 = 0.5$, $\varepsilon_2 = 0.25$, and Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/m^2-K^4, the heat transfer between the plates (in kW/m^2) is ______.

Solution:



Temperature T_1 = 1000 K

Temperature T_2 = 400 K

Emissivity value ε_1 = 0.5

Emissivity value ε_2 = 0.25

Heat transfer between the plates (in kW/m^2) can be calculated using

$$Q = \frac{\sigma\left(T_1^4 - T_2^4\right)}{1/\varepsilon_1 + 1/\varepsilon_2 - 1}$$

$$= \frac{5.67\times10^{-8}\left(1000^4 - 400^4\right)}{1/0.5 + 1/0.25 - 1} = 11049.69$$

$$\approx 11.049 \text{ kW/m}^2$$

Hence, the correct answer is 10.9 – 11.2.

Question Number: 53 **Question Type: NAT**

A cylindrical steel rod, 0.01 m in diameter and 0.2 m in length, is first heated to 750°C and then immersed in a water bath at 100°C. The heat transfer coefficient is 250 W/m^2-K. The density, specific heat, and thermal conductivity of steel are ρ = 7801 kg/m^3, c = 473 J/kg-K, and k = 43 W/m-K, respectively. The time required for the rod to reach 300°C is _______ seconds.

Solution: Diameter of steel rod d = 0.01

Length of steel rod L = 0.2

Temperature to which steel rod is heated T_0 = 750°C

Temperature of water in bath T_∞ = 100°C

Heat transfer coefficient h = 250 W/m^2-K

Density of steel $\rho = 7801$ kg/m^3

Specific heat $c = 473$ J/K

Thermal conductivity $k = 43$ W/mK

Temperature $T_1 = 300^{o}$C

Time required $t = ?$

Now using the relation

$$\frac{T_o - T_\infty}{T_1 - T_\infty} = e^{(hA/\rho VC)t}$$

where area $A = \pi dL$, volume $v = \frac{\pi}{4} d^2 L$)

$$\frac{750-100}{300-100} = e^{\frac{250\pi d L \times 4}{7801 \times \pi d^2 L \times 473} t}$$

$$t = 43.49 \text{ seconds}$$

Hence, the correct answer is 42 – 45.

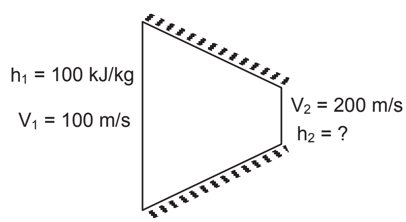
Question Number: 54 **Question Type: NAT**

Steam at an initial enthalpy of 100 kJ/kg and inlet velocity of 100 m/s, enters an insulated horizontal nozzle. It leaves the nozzle at 200 m/s. The exit enthalpy (in kJ/kg) is _________.

Solution: Initial enthalpy $h_1 = 100$ kJ/kg

Inlet velocity $V_1 = 100$ m/s

Velocity when it leaves the nozzle $V_2 = 200$ m/s



Now using the relation

$$h_1 + \frac{V_1^2}{L} = h_2 + \frac{V_2^2}{L}$$

$$\Rightarrow 100 + \frac{100^2 - 200^2}{2000} = h_2$$

$$h_2 = 85 \text{ kJ/kg}$$

Hence, the correct answer is 85.

Question Number: 55 **Question Type: NAT**

In a mixture of dry air and water vapor at a total pressure of 750 mm of Hg, the partial pressure of water vapor is 20 mm of Hg. The humidity ratio of the air in grams of water vapor per kg of dry air (g_w/kg_{da}) is ________.

Solution: Total pressure of mixture of dry air and water vapor $P_{Total} = 750$ mm of Hg

Pressure of water vapor $P_v = 20$ mm of Hg

Humidity ratio of the air $\omega = ?$

Now using the relation

$$\omega = 0.622 \frac{P_v}{P_{Total} - P_v} = 0.622 \times \frac{20}{750-20}$$

$$= 0.622 \times \frac{20}{730}$$

≈ 0.01704 kg/kg dry air

$= 17.04$ g/kg dry air

Hence, the correct answer is 16.9 – 17.1.

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

In a three-stage air compressor, the inlet pressure is p_1, discharge pressure is p_4, and the intermediate pressures are p_2 and p_3 ($p_2 < p_3$). The total pressure ratio of the compressor is 10 and the pressure ratios of the stages are equal. If $p_1 = 100$ kPa, the value of the pressure p_3 (in kPa) is __________.

Solution:

Inlet pressure $P_1 = 100$ kPa

Ratio of discharge pressure and inlet pressure is

$$\frac{P_4}{P_1} = 10$$

For three-stage compression

$$\frac{P_2}{P_1} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = \text{Constant}$$

$$\frac{P_2}{P_1} = 10^{1/3}$$

$$\frac{P_3}{P_1} = 10^{2/3}$$

$\therefore$ $P_3 = P_1 \times 10^{2/3}$

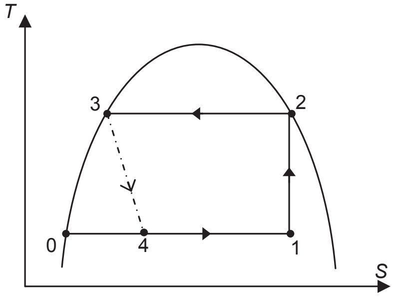
$= 100 \times 10^{2/3} = 464$ kPa

Hence, the correct answer is 460 – 470.

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

In the vapor compression cycle shown in the figure, the evaporating and condensing temperatures are 260 K and 310 K, respectively. The compressor takes in liquid–vapor mixture (state 1) and isentropically compresses it to a dry saturated vapor condition (state 2). The specific heat of the liquid refrigerant is 4.8 kJ/kg-K and may be treated as constant. The enthalpy of evaporation for the refrigerant at 310 K is 1054 kJ/kg.

The difference between the enthalpies at state points 1 and 0 (in kJ/kg) is ________.



Solution: We now that $dQ = C_p dt$

$$s_2 - s_0 = \int_0^3 \frac{C_p dT}{T} + \frac{h_{fg}}{310}$$

$$s_1 - s_0 = 4.8 \ln\left(\frac{310}{260}\right) + \frac{1054}{310}$$

$$\frac{h_1 - h_0}{260} = 4.8 \ln\left(\frac{310}{260}\right) + \frac{1054}{310}$$

$$\Rightarrow \quad h_1 - h_0 = 1103.5 \text{ kJ/kg}$$

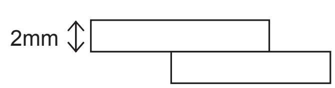
Hence, the correct answer is 1103.5 kJ/kg.

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

Spot welding of two steel sheets each 2 mm thick is carried out successfully by passing 4 kA of current for 0.2 seconds through the electrodes. The resulting weld nugget formed between the sheets is 5 mm in diameter. Assuming cylindrical shape for the nugget, the thickness of the nugget is _______ mm.

Latent heat of fusion for steel	1400 kJ/kg
Effective resistance of the weld joint	200 $\mu\Omega$
Density of steel	8000 kg/m^3

Solution:



Current I = 4 kA= 4000 A

Resistance of weld joint $R = 200 \times 10^{-6}\ \Omega$

Time t = 0.2 s

Density of steel $\rho = 8000$ kg/m^3

Diameter of weld nugget d_n = 5 mm

Latent heat of fusion for steel = 1400 kJ/kg

t_{nugget} = ?

Volume of nugget = $\frac{\pi}{4} d_n^2 \times t_{nugget}$

Heat supplied = $I^2 Rt = 4000^2 \times 0.2 \times 200 \times 10^{-6}$

= 640 J

Heat required to melt = L.H × ρ × volume

$= 1400 \times 10^3 \times 8000 \times \frac{\pi}{4} \times 25 \times 10^{-6} \times t_{nugget} \times 10^{-3}$

$= 219.8\ t_{nugget}$

So, $t_{nugget} = \frac{640}{219.8} = 2.911$ mm

Hence, the correct answer is 2.85 to 2.95.

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

For an orthogonal cutting operation, tool material is HSS, rake angle is 22°, chip thickness is 0.8 mm, speed is 48 m/min, and feed is 0.4 mm/rev. The shear plane angle (in degrees) is

(A) 19.24
(B) 29.70
(C) 56.00
(D) 68.75

Solution: Rake angle $\alpha_0 = 22°$

Chip thickness t_2 = 0.8 mm

Feed t_1 = 0.4 mm/rev

Chip reduction coefficient

$$k = \frac{t_2}{t_1} = 2$$

Let the shear plane angle be θ =?

Now using the relation

$$\tan\theta = \frac{\cos\alpha_0}{k - \sin\alpha_0} = \frac{\cos 22}{2 - \sin 22} = 0.57$$

$\theta = 29.70$

Hence, the correct option is (B).

Question Number: 60 **Question Type: NAT**

In a sheet metal of 2 mm thickness, a hole of 10 mm diameter needs to be punched. The yield strength in tension of the sheet material is 100 MPa and its ultimate shear strength is 80 MPa. The force required to punch the hole (in kN) is _________.

Solution: Thickness of metal sheet t = 2 mm

Diameter of hole d = 10 mm

Ultimate shear strength τ_s = 80 MPa

Yield strength S_{yT} = 100 MPa

Force required to punch the hole can be calculated using the following relation:

$$F = \pi\, dt \ \times \tau_s$$
$$= \pi \times 2 \times 10 \times 80 = 5.026 \text{ kN}$$

Hence, the correct answer is 4.9 – 5.1.

Question Number: 61 **Question Type: NAT**

In a single turning operation with cemented carbide tool and steel work piece, it is found that the Taylor's exponent is 0.25. If the cutting speed is reduced by 50%, then the tool life changes by _______ times.

Solution: If the cutting speed is reduced by 50%, then $V_2 = V_1 / 2$

Taylor's exponent $n = 0.25$

Now using the relation

$$V_1 T_1^n = V_2 T_2^n$$

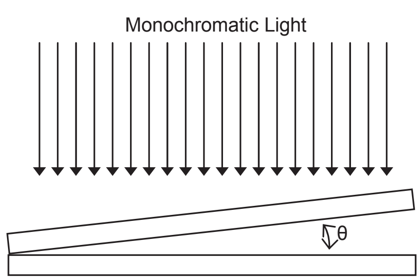
$$V_1 T_1^{0.25} = \frac{V_1}{2} T_2^{0.25}$$

$$\Rightarrow \frac{T_2}{T_1} = 16$$

Hence, the correct answer is 16.

Question Number: 62 **Question Type: NAT**

Two optically flat plates of glass are kept at a small angle θ as shown in the figure. Monochromatic light is incident vertically.



If the wavelength of light used to get a fringe spacing of 1 mm is 450 nm, the wavelength of light (in mm) to get a fringe spacing of 1.5 mm is ________.

Solution: Wavelength of light $\lambda_1 = 450$ mm

Fringe spacing $(\Delta h)_1 = 1$ mm

Fringe spacing $(\Delta h)_2 = 1.5$ mm

Let the wavelength of light (in mm) to get a fringe spacing of 1.5 mm be $\lambda_2 =?$

Now using the relation

$$\Delta h = \frac{n\lambda}{2}$$

$$\frac{(\Delta h)_1}{(\Delta h)_2} = \frac{\lambda_1}{\lambda_2}$$

$$\Rightarrow \frac{1}{1.5} = \frac{450}{\lambda_2} \Rightarrow \lambda_2 = 675 \text{ mm}$$

Hence, the correct answer is 675.

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

A point P (1, 3, −5) is translated by $2\hat{i} + 3\hat{j} - 4\hat{k}$ and then rotated counter clockwise by 90° about the z-axis. The new position of the point is

(A) (–6, 3, –9) (B) (–6, –3, –9)
(C) (6, 3, –9) (D) (6, 3, 9)

Solution: After translation and then angular rotation final point is (–6, 3, –9).

Hence, the correct option is (A).

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

The demand for a two-wheeler was 900 units and 1030 units in April 2015 and May 2015, respectively. The forecast for the month of April 2015 was 850 units. Considering a smoothing constant of 0.6, the forecast for the month of June 2015 is

(A) 850 units (B) 927 units
(C) 965 units (D) 970 units

Solution: Consider the table given below:

	Demand	Forecast
April	900	850
May	1030	

Now the forecast for the month of May will be

$$F_{\text{May}} = F_{\text{April}} + \alpha[D_{\text{April}} - F_{\text{April}}]$$
$$= 850 + 0.6[50]$$
$$= 880$$

And the forecast for the month of June will be

$$F_{\text{June}} = F_{\text{May}} + \alpha[D_{\text{May}} - F_{\text{May}}]$$
$$= 880 + 0.6[1030 - 880]$$
$$= 970$$

Hence, the correct option is (D).

Question Number: 65 **Question Type: NAT**

A firm uses a turning center, a milling center, and a grinding machine to produce two parts. The table below provides the machining time required for each part and the maximum machining time available on each machine. The profit per unit on parts I and II are Rs. 40 and Rs. 100, respectively. The maximum profit per week of the firm is Rs. ________.

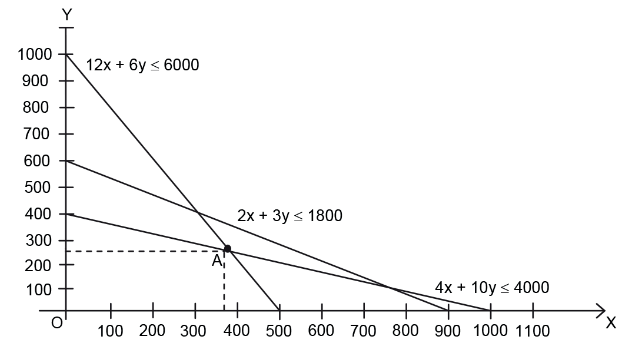
Type of machine	Machining time required for the machine part (minutes) I	II	Maximum machining time available per week (minutes)
Turning center	12	6	6000
Milling center	4	10	4000
Grinding machine	2	3	1800

Solution: Let parts be X and Y

$$Z = 40X + 100Y$$

Constraints

$$12X + 6Y \le 6000$$
$$4X + 10Y \le 4000$$
$$2X + 3Y \le 1800$$



Objective function maximizes at A (375, 250)

Now using

$$Z = 40X + 100Y$$

Substituting $X = 375$ and $Y = 250$ in the above relation, we get

$Z_{max} = 40 \times 375 + 250 \times 100 = 15,000 + 25,000 = 40,000.$

Hence, the correct answer is 40,000.