Aptitude Section

Question 1

"The increased consumption of leafy vegetables in the recent months is a clear indication that the people in the state have begun to lead a healthy lifestyle"

Which of the following can be logically inferred from the information presented in the above statement?

(A) Leading a healthy lifestyle is related to a diet with leafy vegetables.

(B) The people in the state have increased awareness of health hazards causing by consumption of junk foods

(C) The people in the state did not consume leafy vegetables earlier.

(D) Consumption of leafy vegetables may not be the only indicator of healthy lifestyle.

Ans. **A**

Sol. As increased consumption of leafy vegetables is directly proportional to healthy lifestyle. So we can inferred that leading a healthy lifestyle is related to diet with leafy vegetables.

Hence, the correct option is (A).

Question 2

Five persons P, Q, R, S and T are sitting in a row not necessarily in the same order. Q and R are separated by one person, and S should not be seated adjacent to Q.

The number of distinct seating arrangements possible is:

(A) 10 (B) 8 (C) 4 (D) 16

Ans. **D**

Sol. **Step 1 :** Make proper drafting of given information

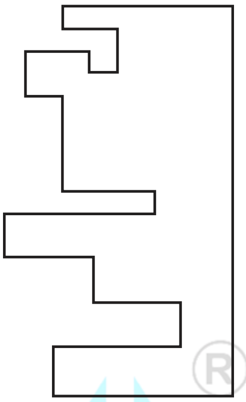
- Q 1 R
- Q × S

Step 2 : Possibilities of seating arrangements.

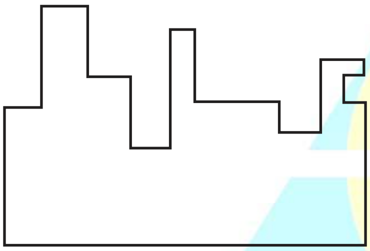
Case 1 :	Q	P	R	S	T
	Q	T	R	S	P
	Q	P	R	T	S
	Q	T	R	P	S
Case 2 :	P	Q	T	R	S
	T	Q	P	R	S
Case 3 :	S	P	Q	T	R
	S	T	Q	P	R
Case 4 :	R	P	Q	T	S
	R	T	Q	P	S
Case 5 :	S	R	P	Q	T
	S	R	T	Q	P
Case 6 :	P	S	R	T	Q
	T	S	R	P	Q
	S	P	R	T	Q

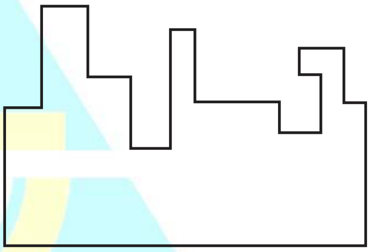
S T R P Q

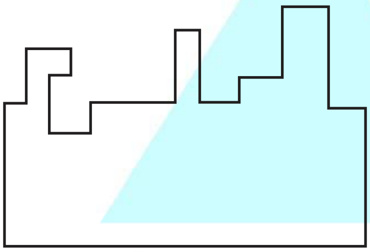
Question 3

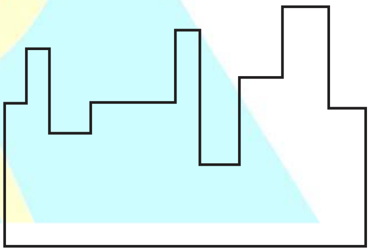


A jigsaw puzzle has 2 pieces. One of the pieces is shown above. Which one of the given options for the missing piece when assembled will form a rectangle? The piece can be moved, rotated or flipped to assemble with the above piece.

(A) 

(B) 

(C) 

(D) 

Ans. **B**

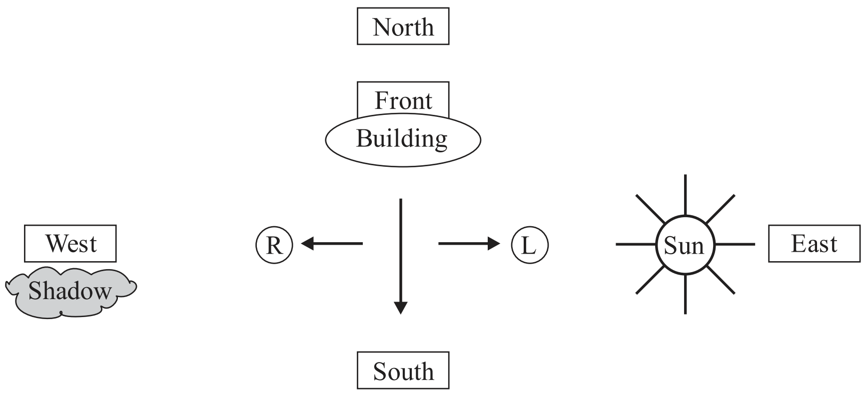
Question 4

Ms. X came out of a building through its front door to find her shadow due to the morning sun falling to her right side with the building to her back. From this, it can be inferred that building is facing_____

(A) North (B) East (C) West (D) South

Ans. **D**

Sol.



Hence, the correct option is (D).

Question 5

$$\text{If}\begin{cases}\text{"}\oplus\text{" means "}-\text{"},\\ \text{"}\otimes\text{" means "}\div\text{"},\\ \text{"}\Delta\text{" means "}+\text{"},\\ \text{"}\nabla\text{" means "}\times\text{"},\end{cases}$$

Then the value of the expression $\Delta 2\oplus 3\Delta((4\otimes 2)\nabla 4)=$

(A) 7 (B) -0.5 (C) -1 (D) 6

Ans. A

Sol. As per the data new equation will be :

Step 1 : $+2-3+((4\div 2)\times 4)$

Step 2 : $2-3+8=7$

Hence the correct option is (A).

Question 6

Oxpeckers and rhinos manifest a symbiotic relationship in the wild. The oxpeckers warn the rhinos about approaching poachers, thus possibly saving the lives of the rhinos. Oxpeckers also feed on the parasitic ticks found on rhinos.

In the symbiotic relationship described above, the primary benefits for oxpeckers and rhinos respectively are.

(A) Oxpeckers get a food source, rhinos may be saved from the poachers.

(B) Oxpeckers get a food source, rhinos have no benefit.

(C) Oxpeckers save their habitat from poachers while the rhinos have no benefit.

(D) Oxpeckers save the lives of poachers, rhinos save their own lives.

Ans. A

Sol. As per the data given in above statement, (A) Oxpeckers get food source, rhinos may be saved from the poachers.

Hence, the correct option is (A).

Question 7

Consider the following statements:

(i) After his surgery, Raja hardly could walk.

(ii) After his surgery, Raja could barely walk.

(iii) After his surgery, Raja barely could walk.

(iv) After his surgery, Raja could hardly walk.

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

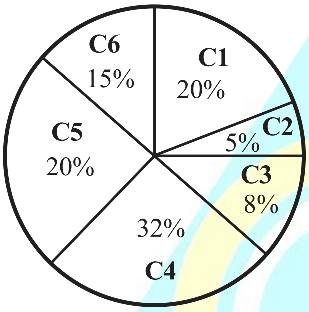
Ans. D

Sol. Grammatically correct statements are :

(i) After his surgery, Raja could barely walk.

(ii) After his surgery, Raja could hardly walk.

Question 8



Company	Ratio
C1	3 : 2
C2	1 : 4
C3	5 : 3
C4	2 : 3
C5	9 : 1
C6	3 : 4

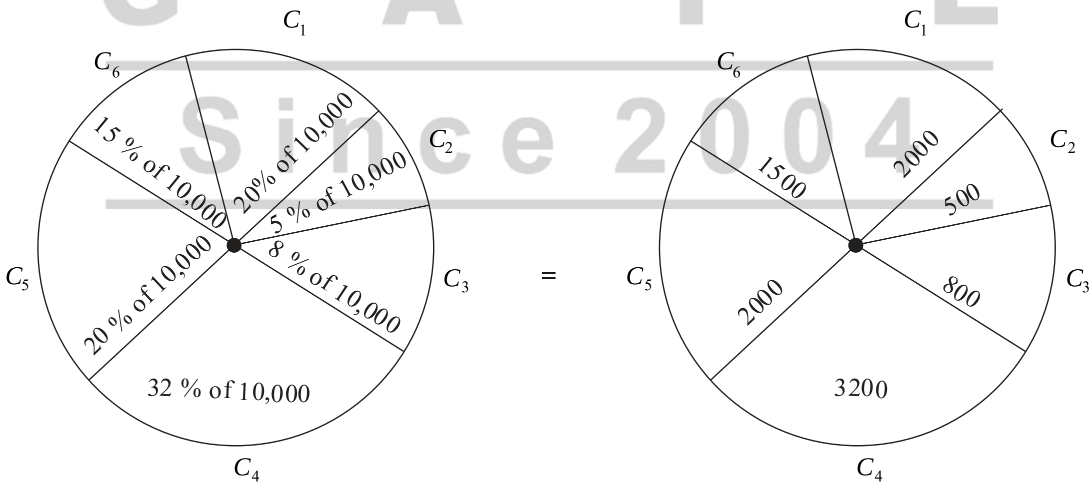
The distribution of employees at the rank of executives, across different companies C1, C2, ….., C6 is presented in the chart given above. The ratio of executives with a management degree to those without a management degree in each of these companies is provided in the table above. The total number of executives across all companies is 10,000.

The total number of management degree holders among the executives in companies C2 and C5 together is __________ .

(A) 2500 (B) 600 (C) 1900 (D) 225

Ans. C

Sol. **Given :** Total number of employees = 10000



$\because$ Management and without management degree ratio = $C_2 = 1:4$ and $C_5 = 9:1$

$\therefore$ Number of management degree executive of C_2 and C_5,

$$C_2 = 500 \times \frac{1}{5} = 100$$

$$C_5 = 2000 \times \frac{9}{10} = 1800$$

Thus, number of management degree employees in C_2 and C_5 together $= 1900$.

Hence, the correct option is (C).

Question 9

The number of hens, ducks and goats in farm P are 65, 91 and 169, respectively. The total number of hens, ducks and goats in a nearby farm *Q* is 416. The ratio of hens:ducks:goats in farm *Q* is 5:14:13. All the hens, ducks and goats are sent from farm *Q* to farm *P*.

The new ratio of hens:ducks:goats in farm *P* is ________

(A) 5:14:13 (B) 10:21:26 (C) 5:7:13 (D) 21:10:26

Ans. **B**

Sol. **Farm *P* :**

$$H_p = 65,\ D_p = 91 \text{ and } G_p = 169$$

Farm *Q* :

$$H_Q + D_Q + G_Q = 416 \qquad \ldots\text{(i)}$$

$$H_Q : D_Q : G_Q = 5:14:13$$

From equation (i),

$$5x + 14x + 13x = 416$$

$$32x = 416$$

$$x = \frac{416}{32} = 13$$

$$H_Q = 5x = 5 \times 13 = 65$$

$$D_Q = 14x = 14 \times 13 = 182$$

$$G_Q = 13x = 13 \times 13 = 169$$

According to question,

$$(H_p + H_Q) : (D_p + D_Q) : (G_p + G_Q)$$

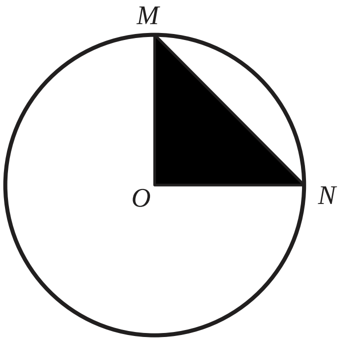
$$(65 + 65) : (91 + 182) : (169 + 169)$$

$$130 : 273 : (2 \times 169)$$

$$10 : 21 : 26$$

Hence, the correct option is (B).

Question 10



In the above figure, O is the center of the circle and, M and N lie on the circle. The area of the right triangle MON is $50\ \text{cm}^2$. What is the area of the circle in cm^2 ?

(A) 2π (B) 50π (C) 100π (D) 75π

Ans. **C**

Sol. Area of triangle $MNO = 50\ \text{cm}^2$

$$\frac{1}{2}\times OM\times ON = 50$$

Since, the radius of circle is $OM = ON = r$

Therefore, $$\frac{1}{2}\times r^2 = 50$$

$$r^2 = 100$$

$$r = 10$$

Then, the area of circle $= \pi r^2 = \pi(10)^2 = 100\pi$

Hence, the correct option is (C).

Technical Section

Question 1

Robot Ltd. wishes to maintain enough safety stock during the lead time period between starting a new production run and its completion such that the probability of satisfying the customer demand during the lead time period is 95%. The lead time period is 5 days and daily customer demand can be assumed to follow the Gaussian (normal) distribution with mean 50 units and a standard deviation of 10 units. Using

$\phi^{-1}(0.95) = 1.64$ where ϕ represents the cumulative distribution function of the standard normal random variable, the amount of safety stock that must be maintained by Robot Ltd. to achieve this demand fulfillment probability for the lead time period is units (round off to two decimal places).

Industrial Engineering (Inventory)

Ans. **16.4**

Sol. **Given :**

Service level = 95%

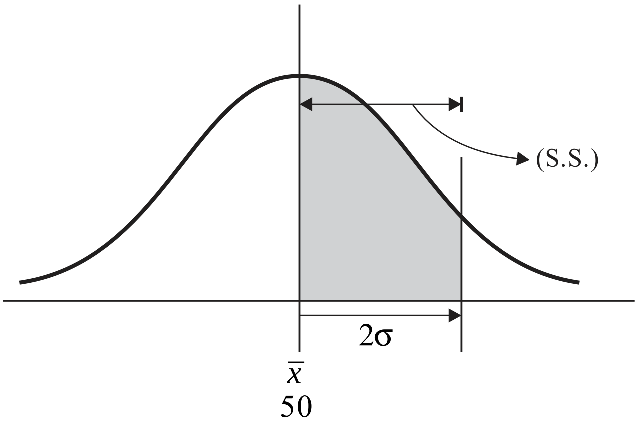
For 95% service level

Z (95%) = 1.64

Lead time = 5 days

Mean, $\bar{X} = 50$ units

Standard deviation, σ = 10 units



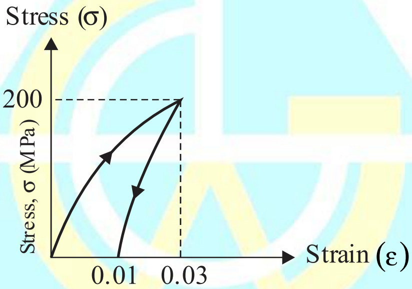
Safety stock, S.S. $= Z\sigma = 1.64 \times 10 = 16.4$ units

Therefore, the probability for the lead time period is 16.4 units.

Question 2

The loading and unloading response of a metal is shown in figure. The elastic and plastic strains corresponding to 200 MPa stress, respectively, are

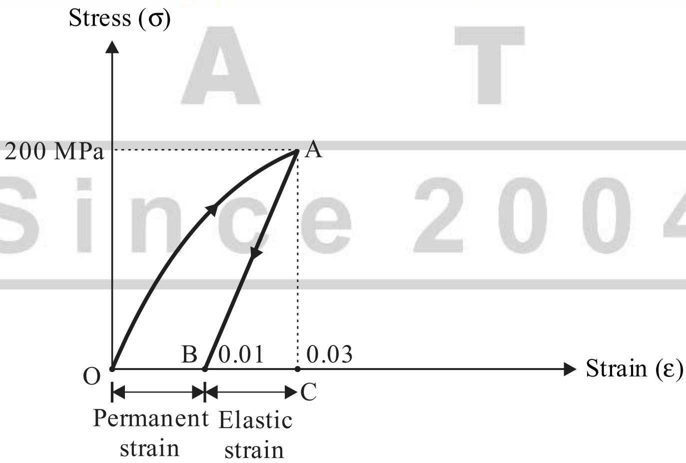
Strength of Material



(A) 0.01 and 0.02 (B) 0.02 and 0.02 (C) 0.02 and 0.01 (D) 0.01 and 0.01

Ans. C

Sol.



Plastic/Permanent strain = OB = 0.01

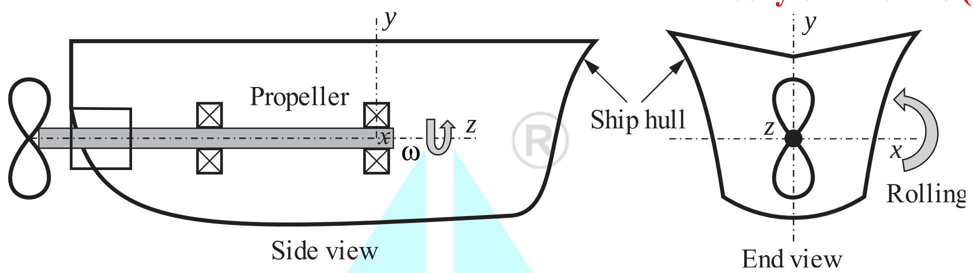
Elastic strain = BC = 0.03 – 0.01 = 0.02

Hence, the correct option is (C).

Question 3

The figure shows an arrangement of a heavy propeller shaft in a ship. The combined polar mass moment of inertia of the propeller and the shaft is 100 $kg.m^2$. The propeller rotates at $\omega = 12$ rad/s. The waves acting on the ship hull induces a rolling motion as shown in the figure with an angular velocity of 5 rad/s. The gyroscopic moment generated on the shaft due to the motion described is ________N.m
(round off to the nearest integer).

Theory of Machine (Gyroscopic)



Ans. *

Sol. **Given :**

$I = 100 \text{ kgm}^2$

$\omega = 12 \text{ rad/s}$

$\omega_p = 5 \text{ rad/s}$

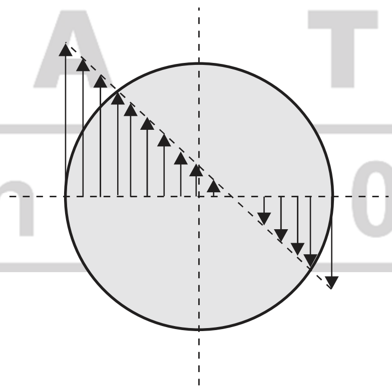
Gyroscopic couple $I\omega \times \omega_p = 100 \times 12 \times 5 = 6000$ Nm

[Reference Book : Theory of Machines by S.S. Rattan]

Question 4

Shear stress distribution on the cross-section of the coil wire in a helical compression spring is shown in the figure. This shear stress distribution represents

Machine Design (Spring)



(A) direct shear stress in coil wire cross-section

(B) combined direct shear and torsional shear stress in the coil wire cross-section

(C) combined direct shear and torsional shear stress along with the effect of stress concentration at inside edge of the coil wire cross-section

(D) torsional shear stress in the coil wire cross-section

Ans. **B**

Sol. Spring is subjected to :

1. Direct shear stress due to load.
2. Torsional shear stress due to load.
3. Shear stress due to curvature at inside edge of coil.

Hence, the correct option is (B).

Question 5

In the vicinity of the triple point, the equation of liquid-vapour boundary in the P – T phase diagram for ammonia is $\ln P = 24.38 - 3063/T$, where P is pressure (in Pa) and T is temperature (in K). Similarly, the solid-vapour boundary is given by $\ln P = 27.92 - 3754/T$. The temperature at the triple point is _______K (round off to one decimal place).

Engineering Thermodynamic (Pure Substance)

Ans. 195.19

Sol. **Given:** Triple point regime for ammonia (NH_3)

$$\ln P = 24.38 - \frac{3063}{T} \Rightarrow \text{liquid vapour line} \quad \ldots \text{(i)}$$

$$\ln P = 27.92 - \frac{3754}{T} \Rightarrow \text{Solid - vapour line} \quad \ldots \text{(ii)}$$

Triple point of any substance, all the three phases coexist with each other in phase equation.

$\therefore$ By equating (i) and (ii),

$$27.92 - \frac{3754}{T} = 24.38 - \frac{3063}{T}$$

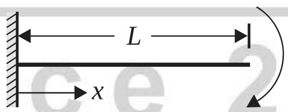
$$(27.92 - 24.38) = \frac{3754 - 3063}{T}$$

$$T = 195.19 \text{ K}$$

Question 6

A cantilever beam of length, L, and flexural rigidity, EI, is subjected to an end moment, M, as shown in the figure. The deflection of the beam at $x = \frac{L}{2}$ is

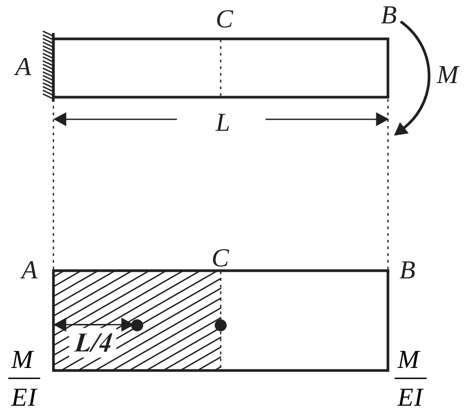
Strength of Material (Deflection)



(A) $\frac{ML^2}{2EI}$ (B) $\frac{ML^2}{16EI}$ (C) $\frac{ML^2}{8EI}$ (D) $\frac{ML^2}{4EI}$

Ans. C

Sol. Applying moment-area method,



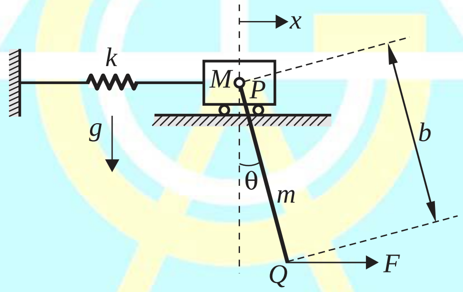
Deflection, $$y_c - y_A = -\frac{M}{EI}\times\frac{L}{2}\times\frac{L}{4}$$

$$y_c = \frac{ML^2}{8EI} \qquad \text{(downwards)}$$

Hence, the correct option is (C).

Question 7

Consider a two degree of freedom system as shown in the figure, where PQ is a rigid uniform rod of length, b and mass, m.



Assume that the spring deflects only horizontally and force F is applied horizontally at Q. For this system, the Lagrangian, L is

Mechanical Vibration (Two Degree of Freedom)

(A) $\frac{1}{2}M\dot{x}^2 + \frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta + \frac{1}{6}mb^2\dot{\theta}^2 - \frac{1}{2}kx^2$

(B) $\frac{1}{2}M\dot{x}^2 + \frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta + \frac{1}{6}mb^2\dot{\theta}^2 - \frac{1}{2}kx^2 + mg\frac{b}{2}\cos\theta + Fb\sin\theta$

(C) $\frac{1}{2}(M+m)\dot{x}^2 + \frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta + \frac{1}{6}mb^2\dot{\theta}^2 - \frac{1}{2}kx^2 + mg\frac{b}{2}\cos\theta$

(D) $\frac{1}{2}(M+m)\dot{x}^2 + \frac{1}{6}mb^2\dot{\theta}^2 - \frac{1}{2}kx^2 + mg\frac{b}{2}\cos\theta$

Ans. C

Sol. Lagrangian, L = Kinetic Energy – Potential Energy

Kinetic Energy of mass M, $K.E = \frac{1}{2}M\dot{x}^2$

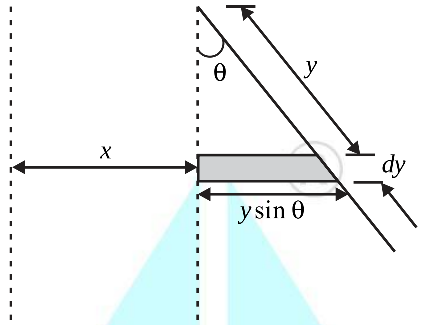
Potential Energy of spring = $\frac{1}{2}kx^2$

Potential Energy of rod $= -mg\dfrac{b}{2}\cos\theta$

Kinetic Energy for rod:

In this system, $(K.E)_i = \dfrac{1}{2}m_i v_i^2$

Rod travels distance *x* and also rotated at an angle θ. We will take a small element *dy* at distance *y* of small mass *dm* (rod).



So, total displacement of rod $= x + y\sin\theta$

And velocity $= \dot{x} + y\cos\theta.\dot{\theta}$

$$(K.E) = \frac{1}{2}(dm)\left[\dot{x} + y\cos\theta.\dot{\theta}\right]^2$$

$$(K.E) = \frac{1}{2}(dm)\left[\dot{x}^2 + y^2.\dot{\theta}^2\cos^2\theta + 2\dot{x}y\dot{\theta}\cos\theta\right]$$

($\because$ θ is small so $\cos^2\theta$ will become 1)

$$(K.E) = \frac{1}{2}(dm)\left[\dot{x}^2 + y^2\dot{\theta}^2 + 2\dot{x}y\dot{\theta}\cos\theta\right]$$

$\because\ dm = \dfrac{m}{b}\times dy$

On putting value of *dm*, we get

$$(K.E) = \frac{1}{2}\frac{m}{b}\times dy\left[\dot{x}^2 + y^2.\dot{\theta}^2 + 2\dot{x}y\dot{\theta}\cos\theta\right]$$

$$(K.E) = \frac{m}{2b}\int_0^b\left[\dot{x}^2 + y^2.\dot{\theta}^2 + 2\dot{x}y\dot{\theta}\cos\theta\right]dy$$

On integrating,

$$(K.E) = \frac{1}{2}\frac{m}{b}\left[\dot{x}^2 b + \frac{\dot{\theta}^2 b^3}{3} + \frac{2\dot{x}\dot{\theta}\cos\theta b^2}{2}\right]$$

$$(K.E)_{rod} = \left[\frac{m\dot{x}^2}{2} + \frac{m\dot{\theta}^2 b^2}{6} + \frac{m\dot{x}\dot{\theta}\cos\theta b}{2}\right]$$

Total Kinetic Energy $= (K.E)_{Total} = (K.E)_M + (K.E)_{rod}$

$$(K.E)_{total} = \frac{M\dot{x}^2}{2} + \frac{m\dot{x}^2}{2} + \frac{m\dot{\theta}^2 b^2}{6} + \frac{m\dot{x}\dot{\theta}\cos\theta b}{2}$$

$$(K.E)_{total} = \frac{(M+m)\dot{x}^2}{2} + \frac{mb\dot{\theta}\dot{x}\cos\theta}{2} + \frac{mb^2\dot{\theta}^2}{6}$$

Total Potential Energy = $(P.E)_{Total} = (P.E)_{Spring} + (P.E)_{rod}$

$$(P.E)_{Total} = \frac{1}{2}kx^2 + \left(-mg\frac{b}{2}\cos\theta\right)$$

$$(P.E)_{Total} = \frac{1}{2}kx^2 - mg\frac{b}{2}\cos\theta$$

Lagrangian, L = (Kinetic Energy)Total – (Potential Energy)Total

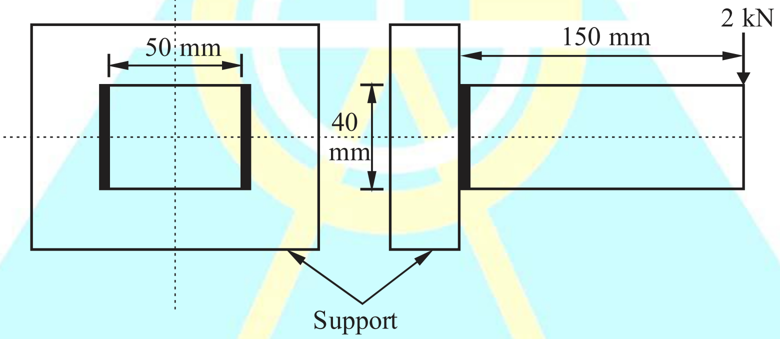
$$L = \left[\frac{1}{2}(M+m)\dot{x}^2 + \frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta + \frac{1}{6}mb^2\dot{\theta}^2\right] - \left[\frac{1}{2}kx^2 - mg\frac{b}{2}\cos\theta\right]$$

$$L = \frac{1}{2}(M+m)\dot{x}^2 + \frac{1}{2}mb\dot{\theta}\dot{x}\cos\theta + \frac{1}{6}mb^2\dot{\theta}^2 - \frac{1}{2}kx^2 + mg\frac{b}{2}\cos\theta$$

Hence, the correct option is (C).

Question 8

A cantilever beam of rectangular cross-section is welded to a support by means of two fillet welds as shown in figure. A vertical load of 2 kN acts at free end of the beam

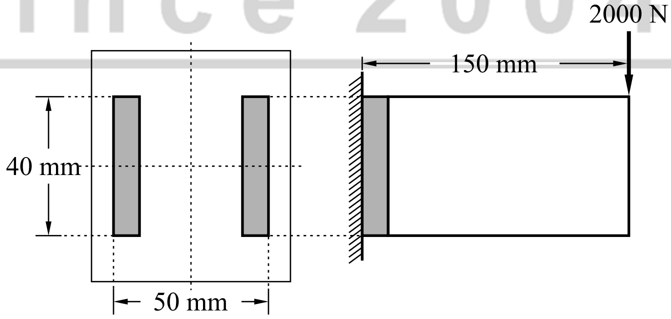


Considering that the allowable shear stress in weld is $60\ \text{N/mm}^2$, the minimum size (leg) of the weld required is ________mm (round off to one decimal place).

Machine Design (Welded joint)

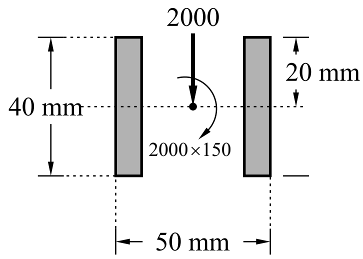
Ans. 6.655

Sol.



Given :

Allowable shear stress, $\tau_p = 60\ \text{N/mm}^2$



$$A_t = 40t + 40t = 80t\ \text{mm}^2$$

$$I_{NA} = \frac{t(40)^3}{12} + \frac{t(40)^3}{12} = \frac{t(40)^3}{6}$$

(i) Primary shear stress (τ'),

$$\tau' = \frac{2000}{80t} = \frac{25}{t}\ \text{N/mm}^2$$

(ii) Maximum bending stress $(\sigma_b)_{\max}$,

$$(\sigma_b)_{\max} = \frac{2000\times 150}{I}\times y_{\max} = \frac{2000\times150\times6}{t(40)^3}\times 20$$

$$(\sigma_b)_{\max} = \frac{562.5}{t}\ \text{N/mm}^2$$

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + (\tau')^2}$$

$$\tau_{\max} = \sqrt{\left(\frac{562.5}{t\times 2}\right)^2 + \left(\frac{25}{t}\right)^2} = \frac{282.35}{t}\ \text{N/mm}^2$$

$$\tau_{\max} \le \tau_p$$

$$\frac{282.35}{t} \le 60$$

$$t \ge 4.706\ \text{mm}$$

$$h > t\sqrt{2}$$

$$h = 6.655\ \text{mm}$$

Question 9

The relative humidity of ambient air at 300 K is 50% with a partial pressure of water vapour equal to p_v. The saturation pressure of water at 300 K is p_{sat}. The correct relation for the air-water mixture is

Refrigeration and air-conditioning (Psychrometry)

(A) $p_v = p_{sat}$ (B) $p_v = 0.622\, p_{sat}$ (C) $p_v = 0.5\, p_{sat}$ (D) $p_v = 2\, p_{sat}$

Ans. **C**

Sol. **Given :** Relative humidity = 50%

Relative humidity $= \frac{p_v}{p_{sat}}$

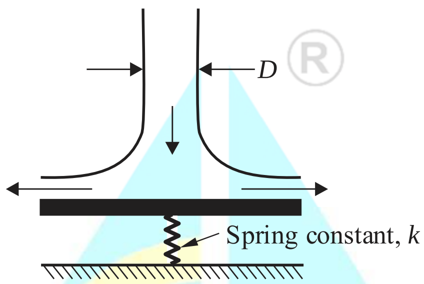
$$0.5 = \frac{p_v}{p_{sat}}$$

$$p_v = 0.5\,p_{sat}$$

Hence, the correct option is (C).

Question 10

A cylindrical jet of water (density = 1000 kg/m^3) impinges at the center of a flat, circular plate and spreads radially outward, as shown in figure. The plate is resting on a linear spring with a spring constant $k = 1$ kN/m. The incoming jet diameter is $D = 1$cm.



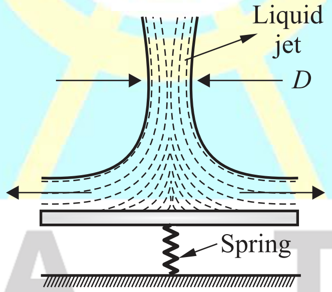
If the spring shows a steady deflection of 1 cm upon impingement of jet, then the velocity of the incoming jet is _________ m/s. (round off to one decimal place)

Fluid Mechanics (Impact of Jet)

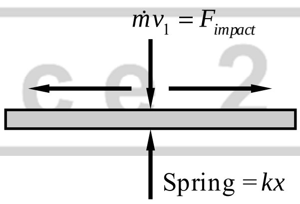
Ans. **11.283**

Sol. **Given :** $\rho = 1000\ \text{kg/m}^3$, $k = 1$ kN/m

$D = 1$ cm, $x = 1$ cm and $V = ?$



Draw FBD of plate,



Balancing the force,

$$kx = \dot{m}v_1$$

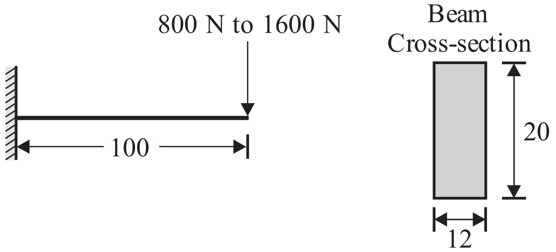
$$kx = (\rho_w a_j v_1)v_1$$

$$v_1^2 = \frac{10}{1000 \times \frac{\pi}{4}(10^{-2})^2 \times (1)}$$

$$v_1 = 11.283 \text{ m/s}$$

Question 11

A machine part in the form of cantilever beam is subjected to fluctuating load as shown in the figure. The load varies from 800 N to 1600 N. The modified endurance, yield and ultimate strengths of the material are 200 MPa. 500 MPa and 600 MPa, respectively.



All dimensions are in mm

The factor of safety of the beam using modified Goodman criterion is_________ (round off to one decimal place).

Machine Design (Dynamic Loading)

Ans. 2

Sol. **Given :** $\sigma_e = 200\,\text{MPa}$

$S_{yt} = 500\,\text{MPa}$

$S_{ut} = 600\,\text{MPa}$

$\sigma_{\max_A} = \sigma_{\max_B}$ at A due to 1600 N $= \dfrac{6M}{bd^2} = \dfrac{6\times1600\times100}{12\times(20)^2}$

$\sigma_{\max_A} = 200\,\text{MPa}$

$\sigma_{\min_A} = \sigma_{\min_B}$ at A due to 800N

$\sigma_{\min_A} = \dfrac{6\times800\times100}{12\times(20)^2} = 100\,\text{MPa}$

Goodman criterion, $\dfrac{\sigma_m}{S_{ut}} + \dfrac{\sigma_a}{\sigma_e} \le \dfrac{1}{\text{N}}$

$$\sigma_m = \left|\frac{\sigma_{\max}+\sigma_{\min}}{2}\right| = 150\,\text{MPa}$$

$$\sigma_a = \left|\frac{\sigma_{\max}-\sigma_{\min}}{2}\right| = 50\,\text{MPa}$$

$$\frac{150}{600}+\frac{50}{200}\le\frac{1}{N}$$

$N \le 2$

$N \approx 2$

Langer, $\dfrac{\sigma_m}{S_{yt}} + \dfrac{\sigma_a}{S_{yt}} \le \dfrac{1}{\text{N}}$

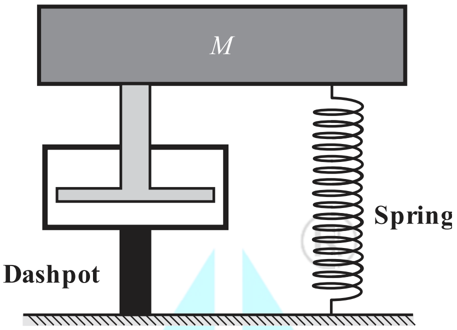
$$\frac{150}{500}+\frac{50}{500}\le\frac{1}{N}$$

$N \le 2.5$

According to modified Goodman criteria, we will select the smaller value of factor of safety from the above two values. So, factor of safety will be 2.

Question 12

Consider a single degree of freedom system comprising a mass M, supported on a spring and a dashpot as shown in the figure



If the amplitude of free vibration response reduces from 8 mm to 1.5 mm in 3 cycles, that damping ratio of the system is _________. (round off to three decimal places).

Mechanical Vibration (Damping Ratio)

Ans. 0.088

Sol.

$$\left.\begin{aligned} x_0 &= 8 \text{ mm} \\ x_3 &= 1.5 \text{ mm} \end{aligned}\right\} 3 \text{ cycle}$$

$$\frac{x_0}{x_3} = e^{3\delta}$$

$$\frac{8}{1.5} = e^{3\delta}$$

$$\delta = 0.558$$

$$\frac{2\pi\xi}{\sqrt{1-\xi^2}} = 0.558$$

$$\xi = 0.088$$

Question 13

Customers arrive at a shop according to the Poisson distribution with a mean of 10 customers/hour. The manager notes that no customer arrives for the first 3 minutes after the shop opens. The probability that a customer arrives within the next 3 minutes is

Industrial Engineering (Queuing Theory)

(A) 0.86 (B) 0.61 (C) 0.50 (D) 0.39

Ans. D

Sol. **Given:** $\lambda = 10$ customer/hours, $t = 3$ minutes $= \frac{3}{60}$ hour

$n = 1$ (for one customer to arrive)

The probability that a customer arrive within the next 3 minutes is,

$$P(n,t) = \frac{e^{-\lambda t}(\lambda t)^n}{n!}$$

$$P(1,3)=\frac{e^{-10\times\frac{3}{60}}\left(10\times\frac{3}{60}\right)^{1}}{1!}$$

$$P(1,3)=0.303$$

Since, the nearest option is D.

Hence, the correct option is (D)

Question 14

An infinitely long pin fin, attached to an isothermal hot surface, transfers heat at a steady rate of $\dot{Q}_1$ to the ambient air. If the thermal conductivity of the fin material is doubled, while keeping everything else constant, the rate of steady-state heat transfer from the fin becomes $\dot{Q}_2$. The ratio $\dot{Q}_2/\dot{Q}_1$ is

Heat Transfer (Fins)

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

Ans. **A**

Sol. Heat transfer with long fin is Q_1 (conductivity $=K$)

$$Q_1=\sqrt{hPKA_C}\,(T_0-T_\infty)$$

Heat transfer with long fin Q_2 (conductivity $=2K$)

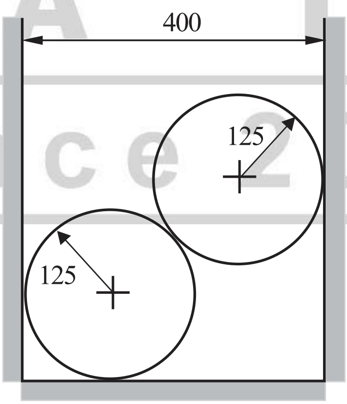
$$Q_2=\sqrt{hP2KA_C}\,(T_0-T_\infty)$$

$$\frac{Q_2}{Q_1}=\frac{\sqrt{hP2KA_C}\,(T_0-T_\infty)}{\sqrt{hPKA_C}\,(T_0-T_\infty)}=\sqrt{2}$$

Hence, the correct option is (A).

Question 15

Two smooth identical spheres each of radius 125 mm and weight 100 N rest in a horizontal channel having vertical walls. The distance between vertical walls of the channel is 400 mm.



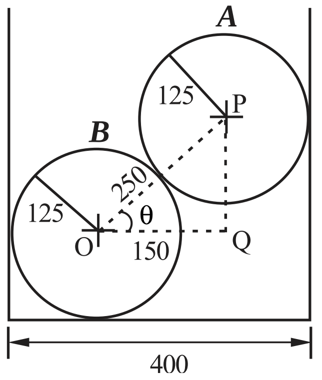
All dimensions are in mm

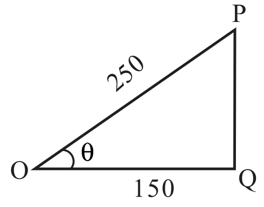
The reaction at the point of contact between two spheres is _____ N (round off to one decimal place).

Engineering Mechanics (Concurrent Force System)

Ans. **125**

Sol.

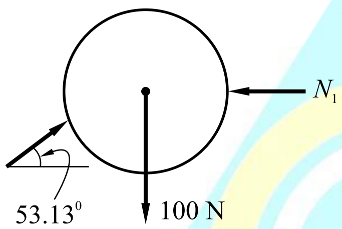


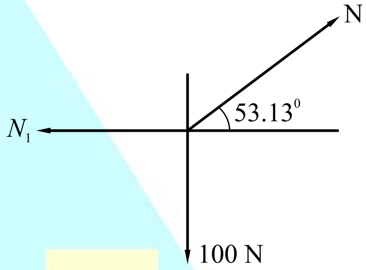


$$\cos\theta = \frac{150}{250} = \frac{OQ}{OP}$$

$$\theta = 53.13^0$$

FBD of body A,





$$N\sin 53.13 = 100$$

$$N = \frac{100}{\sin 53.13} = 125 \text{ N}$$

Question 16

The correct sequence of machining operations to be performed to finish a large diameter through hole is

Production Engineering (Metal Cutting)

(A) drilling, reaming, boring
(B) drilling, boring, reaming
(C) boring, reaming, drilling
(D) boring, drilling, reaming

Ans. B

Sol. Drilling $\rightarrow$ Boring $\rightarrow$ Reaming

Question 17

The Dirac-delta function $(\delta(t-t_0))$ for $t, t_0 \in R$, has the following property

$$\int_a^b \phi(t)\delta(t-t_0)\,dt = \begin{cases} \phi(t_0) & a < t_0 < b \\ 0 & \text{otherwise} \end{cases}$$

The Laplace transform of the Dirac-delta function $\delta(t-a)$ for $a > 0$;

$L\{\delta(t-a)\} = F(s)$ is

Engineering Mathematics (Laplace Transformation)

(A) 0
(B) ∞
(C) e^{sa}
(D) e^{-sa}

Ans. D

Sol. $\delta(t-t_0) = \infty,\ t = t_0$

$$\delta(t-t_0) = 0,\ t \neq t_0$$

$$f(t) \xleftrightarrow{\text{Laplace transform}} F(s)$$

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

For $\delta(t - t_0)$, Laplace transform will be,

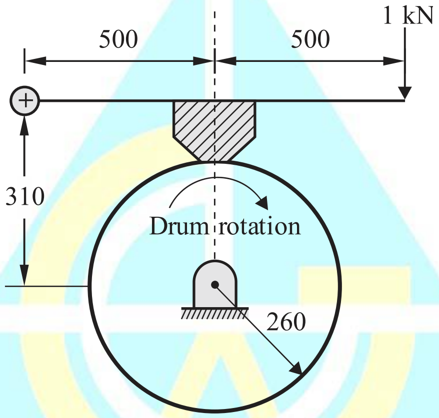
$$\text{Laplace transform } [\delta(t - t_0)] = \int_0^{\infty} \delta(t - t_0) e^{-st} dt$$

$$[\delta(t - t_0)] = e^{-sa} \qquad (\text{for } 0 < a < \infty)$$

Hence, the correct option is (D).

Question 18

A short shoe drum (radius 260 mm) brake is shown in the figure. A force of 1 kN is applied to the lever. The coefficient of friction is 0.4.



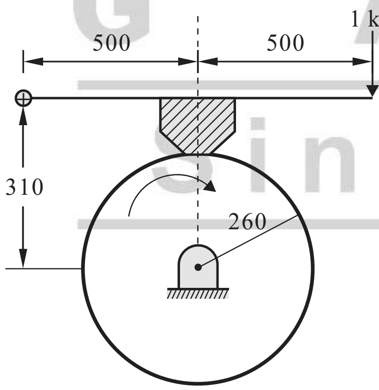
All dimensions are in mm

The magnitude of the torque applied by the brake is ________ N.m (round off to one decimal place).

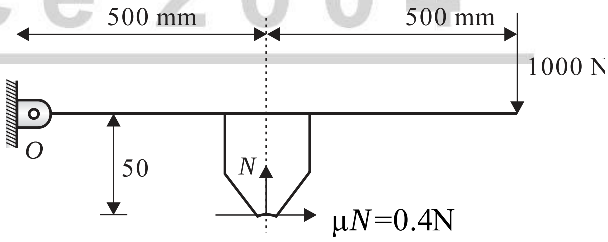
Engineering Mechanics or Machine Design (Brakes)

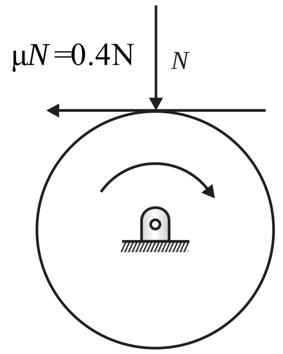
Ans. **200**

Sol.



All dimensions are in mm





In FBD of lever :

Taking moment about O, $\Sigma M_O = 0$

$$(1000\times1000)-(N\times500)-(0.4N\times50)=0$$

$$N = 1923.0768\text{ N}$$

Braking torque, $T_B = \mu N \times r = 0.4\times1923.076\times0.26$

$$T_B = 200\text{ Nm}$$

Question 19

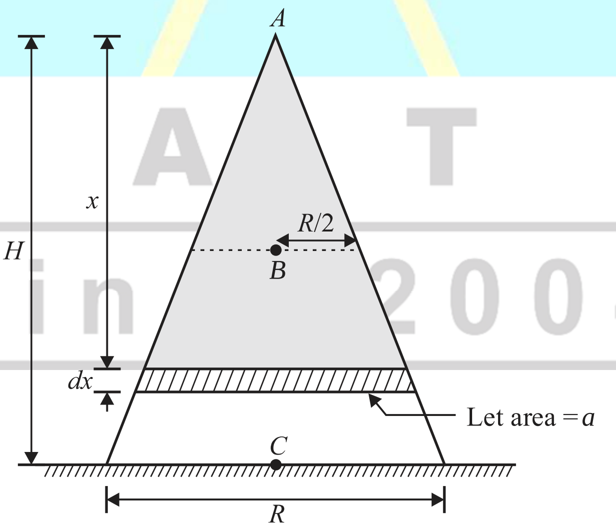
A right solid circular cone standing on its base on a horizontal surface is of height H and base radius R. The cone is made of a material with specific weight w and elastic modulus E. The vertical deflection at the mid-height of the cone due to self-weight is given by

Strength of Material (Deformation Due To Self-Weight)

(A) $\frac{wRH}{6E}$ (B) $\frac{wH^2}{8E}$ (C) $\frac{wRH}{8E}$ (D) $\frac{wH^2}{6E}$

Ans. B

Sol.



Axial force = –weight of shaded region

$$= -w\left(\frac{1}{3}ax\right)$$

$$= -\frac{wax}{3}$$

Displacement of mid point (δ_B)

$$\delta_B = \delta_{B/C} = \int_{H/2}^{H} \frac{\left(-\frac{wax}{3}\right)dx}{aE}$$

$$\delta_B = \delta_{B/C} = -\frac{w}{3E}\left[\frac{x^2}{2}\right]_{H/2}^{H}$$

$$\delta_B = \delta_{B/C} = -\frac{w}{3E}\left[\frac{H^2}{2} - \frac{H^2}{8}\right]$$

$$\delta_B = \delta_{B/C} = -\frac{wH^2}{8E}$$

$$\delta_B = \frac{wH^2}{8E} \text{ (downward)}$$

Hence, the correct option is (B).

Question 20

A resistance spot welding of two 1.55 mm thick metal sheets is performed using welding current of 10000 A for 0.25 second. The contact resistance at the interface of the metal sheets is 0.0001Ω. The volume of weld nugget formed after welding is 70 mm^3. Considering the heat required to melt unit volume of metal is 12 J/mm^3, the thermal efficiency of the welding process is__________ % (round off to one decimal place).

Production Engineering (Welding)

Ans. **33.6**

Sol. **Given :** $t = 1.55$ mm, $I = 10000$ A

$T = 0.25$ sec, $R = 0.0001\ \Omega$

$V = 70\ \text{mm}^3$

Specific heat required for melting $= 12\ \text{J/mm}^3$

$$\eta_{th} = \frac{12\times 70}{I^2RT}\times 100$$

$$\eta_{th} = \frac{12\times 70}{10000^2\times 0.0001\times 0.25}\times 100 = 33.6\%$$

Question 21

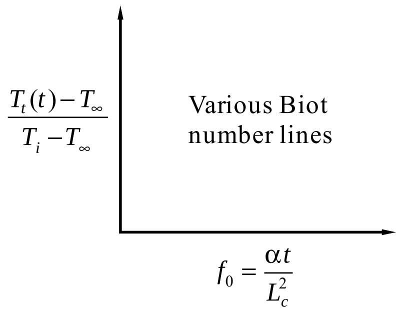
A hot steel spherical ball is suddenly dipped into a low temperature oil bath. Which of the following dimensionless parameters are required to determine instantaneous center temperature of the ball using a Heisler chart?

Heat Transfer (Unsteady State Conduction)

(A) Biot number and Fourier number
(B) Reynolds number and Prandlt number
(C) Nusselt number and Grashoff number
(D) Biot number and Froude number

Ans. **A**

Sol. In case of Heisler chart,



So, Biot number and Fourier number are required to determine instantaneous centre temperature of the ball.

Hence, the correct option is (A).

Question 22

The value of $\lim_{x\to 0}\left(\frac{1-\cos x}{x^2}\right)$ is

Engineering Mathematics (Limit)

(A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) $\frac{1}{3}$ (D) 1

Ans. **B**

Sol. **Given :** $\lim\left(\frac{1-\cos x}{x^2}\right)$

By applying L-H rule

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

$$=\lim_{x\to 0}\frac{\cos x}{2}=\frac{1}{2}$$

Question 23

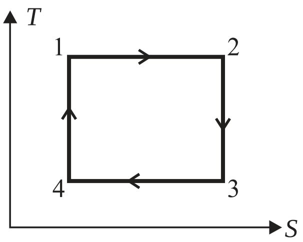
In which of the following pairs of cycles, both cycles have at least one isothermal process?

Application of Thermodynamics (Thermodynamic cycles)

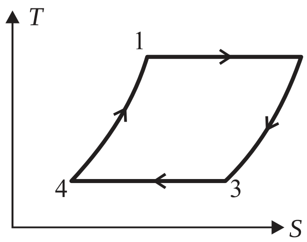
(A) Bell-Coleman cycle and Vapour compression refrigeration cycle
(B) Carnot cycle and Stirling cycle
(C) Brayton cycle and Rankine cycle
(D) Diesel cycle and Otto cycle

Ans. **B**

Sol. Both carnot cycle and stirling cycle include atleast one isothermal process.



carnot cycle



Stirling cycle

Question 24

Consider a vector p in 2-dimensional space. Let its direction (counter-clockwise angle with the positive x-axis) be θ. Let p be an Eigen vector of a 2×2 matrix A with corresponding Eigen value λ, $\lambda>0$. If we denote the magnitude of a vector ν by $\|\nu\|$, identify **VALID** statement regarding p', where $p'=Ap$

Engineering Mathematics (Eigen Values)

(A) Direction of $p'=\lambda\theta, \|p'\|=\|p\|$ (B) Direction of $p'=\theta, \|p'\|=\|p\|/\lambda$

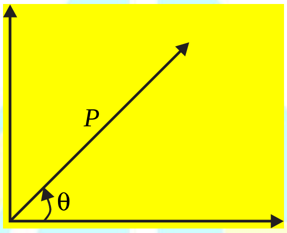
(C) Direction of $p'=\lambda\theta, \|p'\|=\lambda\|p\|$ (D) Direction of $p'=\theta, \|p'\|=\lambda\|p\|$

Ans. D

Sol. We know that,

$$AX=\lambda X \quad \text{.....(i)}$$

According to question, $p'=Ap$ .....(ii)

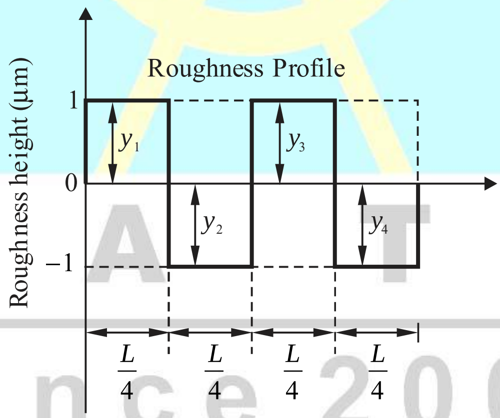


By equating (i) and (ii) we can see that direction will be same.

Hence, the correct option is (B).

Question 25

Consider the surface roughness profile as shown in the figure.



The centre line average roughness (R_a, in μm) of the measured length (L) is

Mechanical Measurement (Roughness)

(A) 2 (B) 0 (C) 4 (D) 1

Ans. D

Sol.

$$R_A=\frac{\text{Total Area}}{L}$$

$$R_A=\frac{4\left(\frac{L}{4}\times1\right)}{L}=1\ \mu m$$

Question 26

In grinding operation of metal, specific energy consumption is 15 J/mm^3. If a grinding wheel with a diameter of 200 mm is rotating at 3000 rpm to obtain a material removal rate of 6000 mm^3/min, then the tangential force on the wheel is _______N(round off to two decimal places).

Production Engineering (Grinding)

Ans. **47.74**

Sol. Specific energy (e) = 15 J/mm^3

$$D = 200 \text{ mm}$$

$$N = 3000 \text{ rpm}$$

$$MRR = 6000 \text{ mm}^3/\text{min}$$

$$e = 15 \text{ J/mm}^3 = \frac{\text{Power}}{MRR}$$

$$\text{Power} = 15 \times 6000$$

$$f_C \times \frac{\pi DN}{1000} = 15 \times 6000$$

$$f_C = \frac{15 \times 6000 \times 1000}{\pi \times 200 \times 3000}$$

$$f_C = 47.74 \text{ N}$$

Question 27

Consider a steam power plant operating on an ideal reheat Rankine cycle. The work input to the pump is 20kJ/kg. The work output from the high pressure turbine is 750 kJ/kg. The work output from the low pressure turbine is 1500 kJ/kg. The thermal efficiency of the cycle is 50%. The enthalpy of saturated liquid and saturated vapour at condenser pressure are 200 kJ/kg and 2600 kJ/kg, respectively. The quality of steam at the exit of the low pressure turbine is _______ %(round off to the nearest integer).

Application of Thermodynamics (Power Plant)

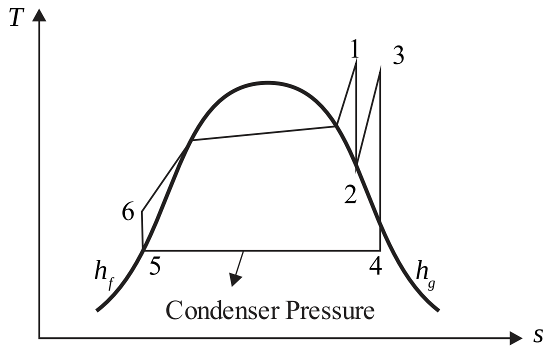
Ans. **92.91**

Sol. **Given :** $W_{HPT_1} = 750$ kJ/kg, $W_{LPT_2} = 1500$ kJ/kg

$$\eta = 50\%, \; W_P = 20 \text{ kJ/kg}$$

$$h_f = 200 \text{ kJ/kg}, \quad h_g = 2600 \text{ kJ/kg}$$

$$\eta = \frac{W_{net}}{Q_{\text{supplied}}}$$



$$W_{net} = W_{HPT_1} + W_{LPT_2} - W_P$$

$$W_{net} = 750 + 1500 - 20 = 2230$$

$$0.50 = \frac{2230}{Q_S} \Rightarrow Q_S = 4460$$

$$\eta = 1 - \frac{Q_R}{Q_S} \Rightarrow 0.50 = 1 - \frac{Q_R}{4460}$$

$$0.50 = \frac{Q_R}{4460}$$

$$Q_R = 2230 \text{ kJ/kg}$$

$$Q_R = h_4 - h_5 = 2230 \text{ kJ/kg} \qquad [h_5 = h_f]$$

For condenser pressure

$$h_4 = h_5 + x(h_g - h_f)$$

$$h_4 - h_5 = x(h_g - h_f)$$

$$2230 = x(2600 - 200)$$

$$x = \frac{2230}{2400} = 0.9291 = 92.91\%$$

Question 28

In modern CNC machine tools, the backlash has been eliminated by

Production Engineering (CNC)

(A) ratchet and pinion (B) rack and pinion

(C) preloaded ballscrews (D) slider crank mechanism

Ans. C

Question 29

Activities A, B, C and D form the critical path for a project with a PERT network. The means and variances of the activity duration for each activity are given below. All activity durations follow the Gaussian (normal) distribution, and are independent of each other.

Activity	A	B	C	D
Mean (days)	6	11	8	15
Variance ($days^2$)	4	9	4	9

The probability that project will be completed within 40 days is_______(round off to two decimal places).

Industrial Engineering (CPM & PERT)

(Note: Probability is a number between 0 and 1).

Ans. **0.5**

Sol.

Activity	A	B	C	D
Mean (days)	6	11	8	15
Variance ($days^2$)	4	9	4	9

A, B, C, D are critical activities

Project duration : 40 days

Probability that project will be completed in **40 days** is

$$Z = \frac{T_S - T_E}{\sigma} = \frac{40-40}{\sigma} \qquad [T_S = 40 \text{ given}]$$

$$Z = 0$$

$$P(Z=0) = 50\% = 0.5$$

Question 30

Consider a reciprocating engine with crank radius R and connecting rod of length L. The secondary unbalance force for this case is equivalent to primary unbalance force due to a virtual crank of__________

Theory of Machine (Balancing)

(A) radius $\frac{L}{2}$ rotating at twice the engine speed

(B) radius $\frac{R^2}{4L}$ rotating at twice the engine speed

(C) radius $\frac{R}{4}$ rotating at half the engine speed

(D) radius $\frac{L^2}{4R}$ rotating at half the engine speed

Ans. **B**

Sol. Primary unbalance = Secondary unbalance

$$mr\omega^2 \cos\theta = \frac{mr\omega^2}{n}\cos\theta$$

For secondary, $r = \frac{r}{4n} = \frac{R \times R}{4 \times L} = \frac{R^2}{4L}$

$$\omega = 2\omega$$

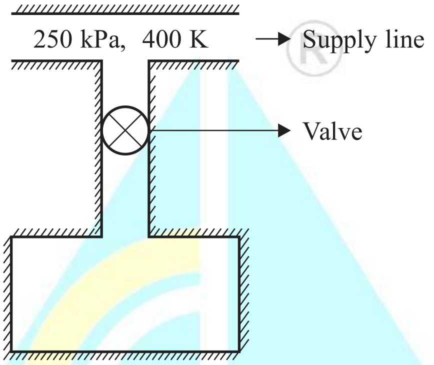
Question 31

A rigid insulated tank is initially evacuated. It is connected through a valve to supply line that carries air at a constant pressure and temperature of 250 kPa and 400 K respectively. Now the valve is opened and air is allowed to flow into the tank until the pressure inside the tank reaches to 250 kPa at which point the valve is closed. Assume that the air behaves as a perfect gas with constant properties $(c_p = 1.005 \text{ kJ/kgK},\ c_v = 0.718 \text{ kJ/kgK},\ R = 0.287 \text{ kJ/kgK})$. Final temperature of the air inside the tank is ___________ K (round off to one decimal place).

Engineering Thermodynamics (Unsteady Flow Problem)

Ans. 560

Sol. Given : Initially evacuated tank rigid and insulated.



$$(P_F)_{\text{inside tank}} = 250 \text{ kPa}$$

$$C_P = 1.005 \text{ kJ/kg-K}$$

$$C_V = 0.718 \text{ kJ/kg-K}$$

$$\gamma = \frac{C_P}{C_V} = 1.39972 \simeq 1.4$$

Using unsteady flow energy equation :

$$\frac{dU_{CV}}{dt} = \dot{m}_i h_i - \underbrace{\dot{m}_e h_e}_{\text{no exit}} + \underbrace{d\dot{Q}}_{\text{insulated}} - \underbrace{d\dot{W}}_{\text{rigid}}$$

$$\frac{dU_{CV}}{dt} = \dot{m}_i h_i - \underbrace{\dot{m}_e h_e}_{\text{no exit(0)}} + \underbrace{d\dot{Q}}_{\text{insulated(0)}} - \underbrace{d\dot{W}}_{\text{rigid(0)}}$$

$$\frac{dU_{CV}}{dt} = \left(\frac{dm}{dt}\right) h_i$$

$$U_2 - U_1 = \underbrace{(m_2 - m_1)}_{\text{initially evacuated}} h_i$$

$$\underbrace{(m_1 u_1)}_{\text{initially evacuated}}$$

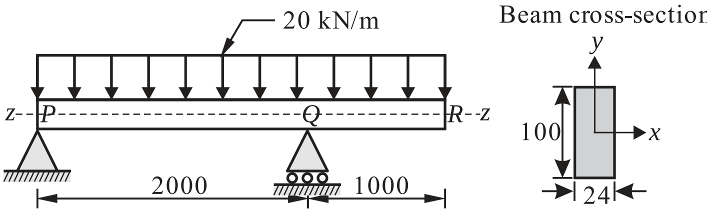
$$m_2 u_2 = m_2 h_i \quad \Rightarrow \quad C_V T_2 = C_P T_i$$

$$T_2 = \gamma T_i \quad \Rightarrow \quad T_2 = 1.4\ (400)$$

$$T_2 = 560 \text{ K}$$

Question 32

An overhanging beam PQR is subjected to uniformly distributed load 20 kN/m as shown in the figure.



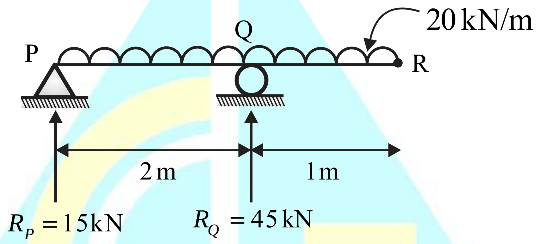
All dimensions are in mm

The maximum bending stress developed in the beam is_______MPa (round off to one decimal place).

Strength of Material (Bending Stresses)

Ans. **250**

Sol.



Taking $\Sigma M_A = 0$,

$$R_Q \times 2 - (20 \times 3 \times 1.5) = 0$$

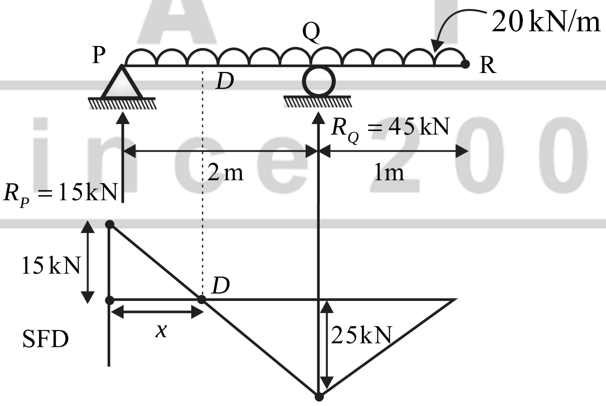
$$R_Q = 45 \text{ kN}$$

Taking $\Sigma F_y = 0$,

$$R_P + R_Q = 60$$

$$R_P + 45 = 60$$

$$R_P = 15 \text{ kN}$$



$$\frac{x}{15} = \frac{2-x}{25}$$

$$25x = 30 - 15x$$

$$x = 0.75 \text{ m}$$

For $(BM)_P = 0$

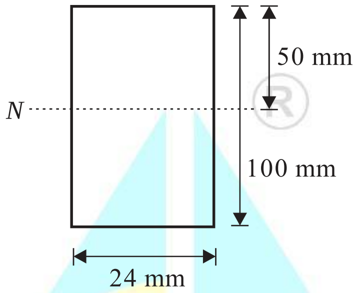
For $(BM)_D = 15x - \frac{20x^2}{2} = 5.625$ kNm

For $(BM)_Q = -20 \times 1 \times \frac{1}{2} = -10$ kNm

For $(BM)_R = 0$

$$M_{max} = 10 \text{ kNm}$$

$$M_{max} = 10 \times 10^6 \text{ Nmm}$$



$$I = \frac{24 \times 100^3}{12}$$

$$(\sigma_0)_{max} = \frac{M_{max}}{I} y_{max}$$

$$(\sigma_0)_{max} = \frac{10 \times 10^6 \times 12}{24 \times 100^3} \times 50 = 250 \text{ MPa}$$

Question 33

A pressure measurement device fitted on the surface of a submarine located at a depth of H below the surface of an ocean, reads an absolute pressure of 4.2 MPa . The density of sea water is 1050 kg/m^3, the atmospheric pressure is 101 kPa, and the acceleration due to gravity is 9.8 m/s^2. The depth H is __________ m.

Fluid Mechanics (Pressure Measurement)

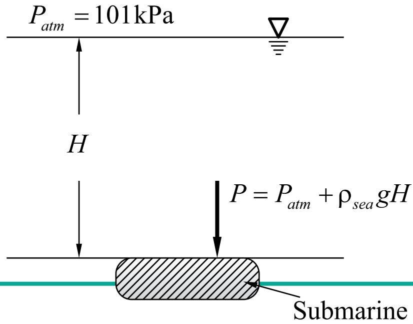
Ans. 398.347

Sol. Given :

$$P_{atm} = 101 kPa$$

$$P = 4.2 \text{ MPa} = 4.2 \times 10^6 \text{Pa}$$

$$\rho_{sea} = 1050 \, kg/m^3$$



$$P = P_{atm} + \rho_{aea}\, gH$$

$$4.2\times10^{6}=101\times10^{3}+1050\times9.8\times H$$
$$H=398.347 \text{ m}$$

Question 34

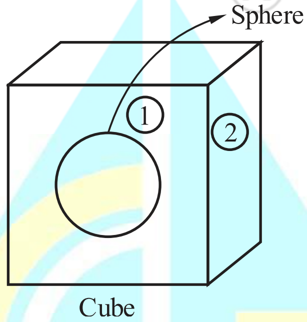
A solid sphere of radius 10 mm is placed at the centroid of a hollow cubical enclosure of side length 30 mm. The outer surface of the sphere is denoted by 1 and the inner surface of the cube is denoted by 2. The view factor F_{22} for radiation heat transfer is _______ (round off to two decimal places).

Heat Transfer (Shape Factor)

Ans. 0.7641

Sol. Given : $R=10$ mm

$L=30$ mm



Surface 1 is a convex surface (sphere)

So, $F_{11}=0$

$$F_{11}+F_{12}=1$$
$$F_{12}=1$$

Apply reciprocal theorem,

$$A_1F_{12}=A_2\times F_{21}$$
$$4\pi R^2\times1=6L^2\times F_{21}$$
$$4\pi(10\times10^{-3})^2=6(30\times10^{-3})^2\times F_{21}$$
$$F_{21}=\frac{0.001256}{0.0054}=0.23259$$
$$F_{21}+F_{22}=1$$
$$F_{22}=1-0.23259$$
$$F_{22}=0.7641$$

Question 35

Superheated steam at 1500 kPa, has a specific volume of $2.75\text{ m}^3/\text{kmol}$ and compressibility factor (Z) of 0.95. The temperature of steam is ______ ^{0}C .(round of to the nearest integer).

Engineering Thermodynamics (Pure Substance)

(A) 522 (B) 471 (C) 249 (D) 198

Ans. C

Sol. **Given :** $P = 1500$ kPa, $v = 2.75$ m^3/kmol

$Z = 0.95$

$T = ?$

$$Pv = Z\bar{R}T$$

$\bar{R}$ = Universal gas constant = 8.314 kJ/kmol-K

$$1500 \times 2.75 = 0.95 \times 8.314 \times T$$

$$T = \frac{1500 \times 2.75}{0.95 \times 8.314} = 522.26 \text{ K}$$

$$T = 249.26^0 \text{C}$$

Question 36

The *XY* table of a *NC* machine tool is to move from P (1,1) to Q (51, 1): all coordinates are in mm. The pitch of the *NC* drive leadscrew is 1 mm. If the backlash between the leadscrew and nut is 1.8^0, then the total backlash of the table on moving from P to Q is ____mm (round off to two decimal places).

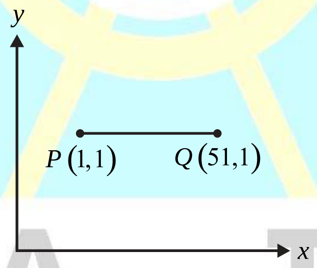
Production Engineering (NC Machines)

Ans. **0.25**

Sol. In one rotation $\rightarrow$ 1 mm

and backlash for one rotation is 1.8^0

So, backlash in mm $= \frac{1.8^0}{360^0} \times 1 = 0.005$ mm



For 50 mm $\rightarrow$ 50 rotation

So in one rotation backlash is 0.005 mm.

For 50 rotation $\rightarrow$ $50 \times 0.005 = 0.25$ mm

Question 37

The fundamental thermodynamic relation for a rubber band is given by $dU = TdS + \tau\, dL$, where T is absolute temperature, S is the entropy, τ is the tension in the rubber band, and L is the length of the rubber band. Which one of the following relations is **CORRECT:**

Engineering Thermodynamics (Thermodynamic Relations)

(A) $\left(\frac{\partial T}{\partial S}\right)_L = \left(\frac{\partial \tau}{\partial L}\right)_S$

(B) $\tau = \left(\frac{\partial U}{\partial S}\right)_L$

(C) $T = \left(\frac{\partial U}{\partial S}\right)_\tau$

(D) $\left(\frac{\partial T}{\partial L}\right)_S = \left(\frac{\partial \tau}{\partial S}\right)_L$

Ans. **D**

Sol. **Given:** Rubber thermodynamic relation :

$dU = TdS + \tau dL$

$\tau =$ Tension in rubber (N)

$L =$ Length of rubber (m)

Correct solution shall be :

$$\left(\frac{\partial T}{\partial L}\right)_S = \left(\frac{\partial \tau}{\partial S}\right)_L$$

Question 38

The ordinary differential equation $\frac{dy}{dt} = -\pi y$ subject to an initial condition $y(0) = 1$ is solved numerically using the following scheme:

$$\frac{y(t_{n+1}) - y(t_n)}{h} = -\pi y(t_n)$$

Where h is the time step, $t_n = nh$, and $n = 0, 1, 2, \ldots\ldots$ This numerical scheme is stable for all values of h in the interval______.

Engineering Mathematics (Differential Equations)

(A) For all $h > 0$ (B) $0 < h < 1$ (C) $0 < h < 2/\pi$ (D) $0 < h < \pi/2$

Ans. **C**

Sol. $y_{n+1} = y_n + hf(x_n, y_n)$

$y_{n+1} = y_n + h(-\pi y_n)$

$y_{n+1} = y_n(-1 - \pi h)$

For stable system: $|1 - \pi h| < 1$

$-1 < (1 - \pi h) < 1$

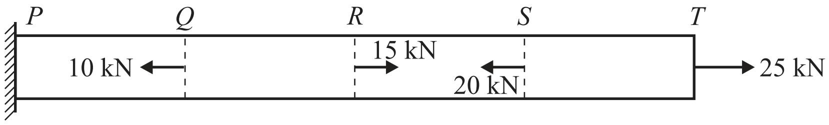
$-2 < (-\pi h) < 0$

$\frac{2}{\pi} > h > 0$

Hence, the correct option is (C)

Question 39

A prismatic bar $PQRST$ is subjected to axial loads as shown in the figure. The segments having maximum and minimum axial stresses, respectively, are

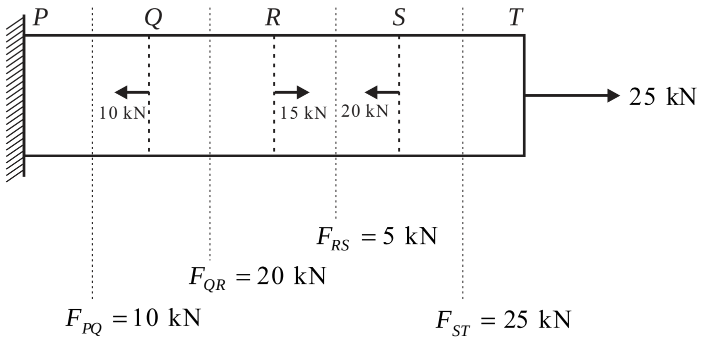


Strength of Material (Axial Loading)

(A) QR and PQ (B) ST and PQ (C) ST and RS (D) QR and RS

Ans. **C**

Sol.



$F_{\min} = 5$ kN in RS portion $\qquad \sigma_{\min} = \dfrac{F_{\min}}{A}$ in RS portion

$F_{\max} = 25$ kN in ST portion $\qquad \sigma_{\max} = \dfrac{F_{\max}}{A}$ in ST portion

Hence, the correct option is (C).

Question 40

A set of jobs A, B, C, D, E, F, G, H arrive at time $t = 0$ for processing on turning and grinding machines. Each job needs to be processed in sequence-first on the turning machine and second on the grinding machine, and the grinding must occur immediately after turning. The processing times of the jobs are given below.

Job	A	B	C	D	E	F	G	H
Turning (Minutes)	2	4	8	9	7	6	5	10
Grinding (Minutes)	6	1	3	7	9	5	2	4

If the makespan is to be minimized, then the optimal sequence in which these jobs must be processed on the turning and grinding machines is

Industrial Engineering (Sequencing)

(A) A-D-E-F-H-C-G-B (B) B-G-C-H-F-D-E-A
(C) G-E-D-F-H-C-A-B (D) A-E-D-F-H-C-G-B

Ans. **D**

Sol.

	Sequencing							
	A	B	C	D	E	F	G	H
Turning	2	4	8	9	7	6	5	10
Grinding	6	1	3	7	9	5	2	4

Applying Johnson's rule

Find minimum processing time and if it is from machine 1, sequenced it from start side and if it is from machine 2 sequenced from end side.

A E D (Start →)   F H C G B (← end)

Answer : A - E - D - F - H - C - G - B

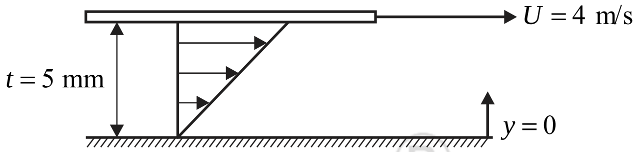
Question 41

Consider fully developed, steady state incompressible laminar flow of a viscous fluid between two large parallel horizontal plates. The bottom plate is fixed and the top plate moves with a constant velocity of $U = 4$ m/s. Separation between the plates is 5 mm. There is no pressure gradient in the direction of flow. The density of fluid is $800\,\text{kg/m}^3$, and the kinematic viscosity is $1.25\times10^{-4}\,\text{m}^2/\text{s}$. The average shear stress in the fluid is ________ Pa (round off to the nearest integer).

Fluid Mechanics (Laminar Flow)

Ans. 80

Sol. **Given :** $\rho = 800\ \text{kg/m}^3,\ \nu = 1.25\times10^{-4}\ \text{m}^2/\text{s}$



For plane coutte flow

Linearization of Newton's law of viscosity is used

$$\tau = \mu\frac{du}{dy} = \mu\frac{U}{t} \qquad [\because\ \mu = \rho\nu]$$

$$\tau = (800\times1.25\times10^{-4})\times\frac{4}{5\times10^{-3}}$$

$$\tau = 80\ \text{Pa}$$

Question 42

A 200 mm wide plate having a thickness of 20 mm is fed through a rolling mill with two rolls. The radius of each roll is 300 mm. The plate thickness is to be reduced to 18 mm in one pass using a roll speed of 50 rpm. The strength coefficient (K) of the work material flow curve is 300 MPa and the strain hardening exponent, n is 0.2. The coefficient of friction between the rolls and the plate is 0.1. If the friction is sufficient to permit the rolling operation then the roll force will be____________ kN (round off to the nearest integer).

Production Engineering (Rolling)

Ans. 930

Sol. **Given :** $w = 200$ mm, $h_0 = 20$ mm

$R = 300$ mm, $h_f = 18$ mm

$k = 300$ MPa, $n = 0.2$ and $\mu = 0.1$

$$\sigma_0 = \frac{k\varepsilon_T^n}{n+1}$$

$$\sigma_0 = \frac{300\times\left|\ln\left(\frac{18}{20}\right)\right|^{0.2}}{1.2}$$

$$\sigma_0 = 159.39\,\text{MPa}$$

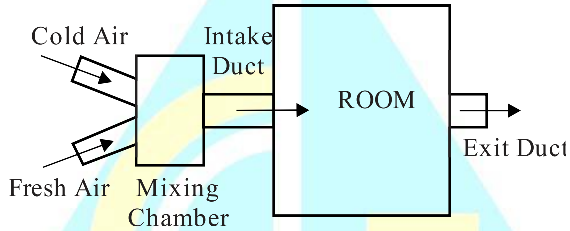
$$F = \frac{2}{\sqrt{3}}\times159.39\times\sqrt{300\times2}\times200$$

$$F = \left[1 + \frac{0.1\sqrt{300\times 2}}{4\times 19}\right]$$

$$F = 930 \text{ kN}$$

Question 43

An air-conditioning system provides a continuous flow of air to a room using an intake duct and an exit duct, as shown in the figure. To maintain the quality of the indoor air, the intake duct supplies a mixture of fresh air with a cold air stream. The two streams are mixed in an insulated mixing chamber located upstream of the intake duct. Cold air enters the mixing chamber at 5° C, 105 kPa with a volume flow rate of 1.25 m^3/s during steady state operation. Fresh air enters the mixing chamber at 34° C and 105 kPa. The mass flow rate of the fresh air is 1.6 times of the cold air stream. Air leaves the room through the exit duct at 24° C



Assuming the air behaves as an ideal gas with $C_p = 1.005$ kJ/kg.K and R=0.287 kJ/kg.K, the rate of heat gain by the air from the room is________kW (round off to two decimal places).

Refrigeration and Air-conditioning (Mixing of Fluids)

Ans. 4.96

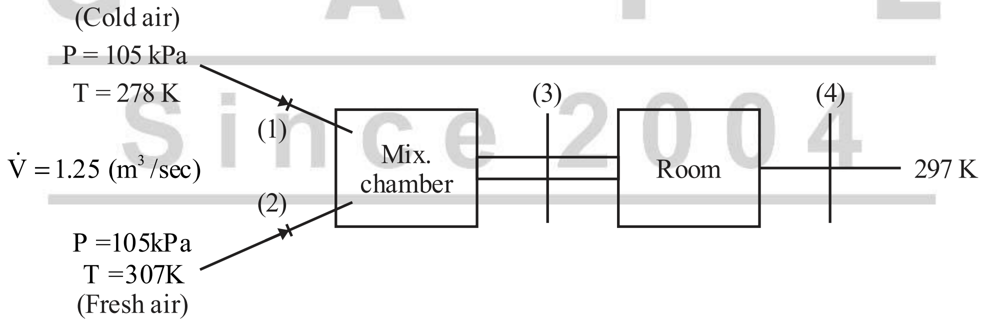
Sol. Given: $\dot{m}_f = 1.6\dot{m}_c$

Temperature of fresh air $= 34^0$C,

Temperature of cold air $= 5^0$C,

Specific heat at constant pressure, $(C_P) = 1.005$ kJ/kgK

Characteristic gas constant, $(R) = 0.287$ kJ/ kgK



$\dot{Q}_{air} = ?$

State 1 :

$$P\dot{V} = \dot{m}RT$$

$$(105)\times 1.25 = \dot{m}\times 0.287\times 278$$

$$\dot{m}_c = 1.645 \text{ kg/sec}$$

$$\dot{m}_f = 1.6(\dot{m}_c)$$

$$\dot{m}_f = (1.6)(1.645)$$
$$\dot{m}_f = 2.632 \text{ kg/sec}$$

Energy balance for mixing chamber :

$$(\dot{m}_c h_c) + (\dot{m}_f h_f) = (\dot{m}_c + \dot{m}_f)h$$
$$[(1.645)\times 1.005\times 278] + [(2.632)\times 1.005\times 307] = [(1.645 + 2.632)\times 1.005\times T]$$
$$T = 295.85 \text{ K}$$

Load calculation for the room (heat taken by the air)

$$\dot{Q} = \dot{m} C_p \Delta T$$
$$\dot{Q} = (1.645 + 2.632)\times 1.005\times(297 - 295.85)$$
$$\dot{Q} = 4.96 \text{ kW}$$

Question 44

A true centrifugal casting operation needs to be performed horizontally to make copper tube section with outer diameter of 250 mm and inner diameter of 230 mm. The value of acceleration due to gravity, g = 10 m/s^2. If a *G-factor* (ratio of centrifugal force to weight) of 60 is used for casting the tube, the rotational speed required is______ rpm (round off to the nearest integer).

Production Engineering (Casting)

Ans. **661.59**

Sol. **Given :** $OD = 250$ mm, $ID = 230$ mm

$$g = 10 \text{ m/s}^2$$
$$G.F. = \frac{f_c}{f_g}$$
$$60 = \frac{mr\omega^2}{mg}$$
$$60\times g = 125\times 10^{-3}\times\omega^2$$
$$\omega^2 = 4800$$
$$\frac{2\pi N}{60} = \sqrt{4800}$$
$$N = \frac{\sqrt{4800}\times 60}{2\pi} = 661.59 \text{ rpm}$$

Question 45

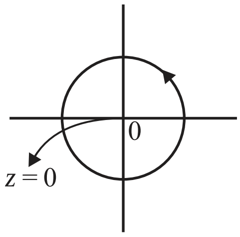
Let C represent the unit circle centered at origin in the complex plane, and complex variable, $z = x + iy$. The value of the contour integral $\oint_c \frac{\cosh(3z)}{2z}dz$ (where integration is taken counter clockwise) is

Engineering Mathematics (Complex Variable)

(A) $2\pi i$ (B) πi (C) 0 (D) 2

Ans. **B**

Sol. $I = \oint_c \frac{\cosh(3z)}{2z} dz$



$$\frac{1}{2}\oint \frac{\cosh(3z)}{(z-0)} = \frac{1}{2} \times 2\pi i \times f(a) = \pi i \times \cosh(0)$$

$$I = \pi i$$

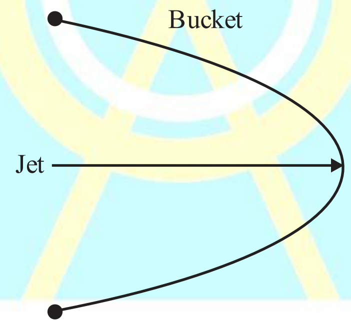
Question 46

A single jet Pelton wheel operates at 300 rpm. The mean diameter of the wheel is 2 m. Operating head and dimensions of jet are such that water comes out of the jet with a velocity of 40 m/s and flow rate of $5\,m^3/sec$. The jet is deflected by the bucket at an angle of 165^0. Neglecting all losses, the power developed by the Pelton wheel is ________MW (round off to two decimal places).

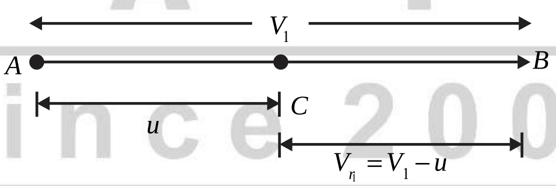
Hydraulic Machine (Pelton Wheels)

Ans. **2.6499**

Sol. **Given** $V_1 = 40$ m/s, $Q = 5$ m^3/s, $\delta = 165^0$, $N = 300$ rpm



At inlet :

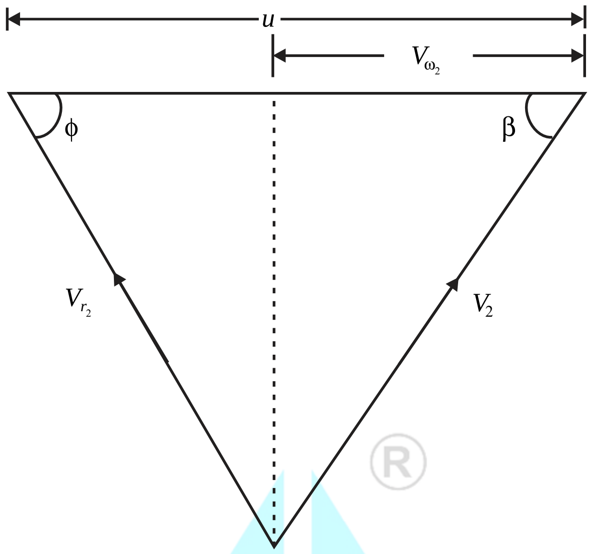


$$u = \frac{\pi DN}{60} = \frac{\pi \times 2 \times 300}{60}$$

$$= 31.415 \text{ m/sec}$$

$$V_{w_1} = V_1 = 40 \text{ m/sec}$$

At exit:



Blade are smooth so,

$$V_{r_1} = V_{r_2} = V_1 - u$$

$$= 40 - 31.42$$

$$= 8.58 \text{ m/sec}$$

$$V_{w_2} = u - V_{r_2} \cos\phi$$

$$= 31.42 - 8.58 \cos 15^0$$

$$= 23.132 \text{ m/sec}$$

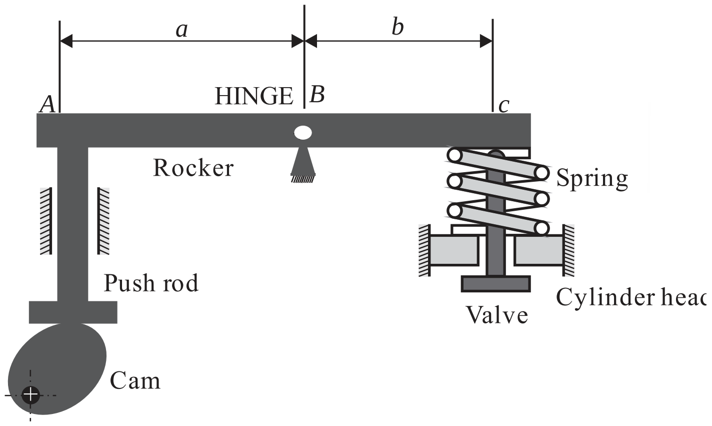
$$\text{Power in MW} = \frac{\rho Q(V_{w_1} - V_{w_2})u}{10^6}$$

$$= \frac{1000 \times 5[40 - 23.132] \times 31.42}{10^6}$$

$$= 2.6499 \text{ MW}$$

Question 47

A tappet valve mechanism in an IC engine comprises a rocker arm ABC that is hinged at B as shown in the figure. The rocker is assumed rigid and it oscillates about the hinge B. The mass moment of inertia of the rocker about B is 10^{-4} kg.m^2. The rocker arm dimensions are $a = 3.5$ cm and $b = 2.5$ cm. A pushrod pushes the rocker at location A, when moved vertically by a cam that rotates at N rpm. The pushrod is assumed massless and has a stiffness of 15 N/mm. At the other end C, the rocker pushes a valve against a spring of stiffness 10 N/mm. The valve is assumed mass-less and rigid.



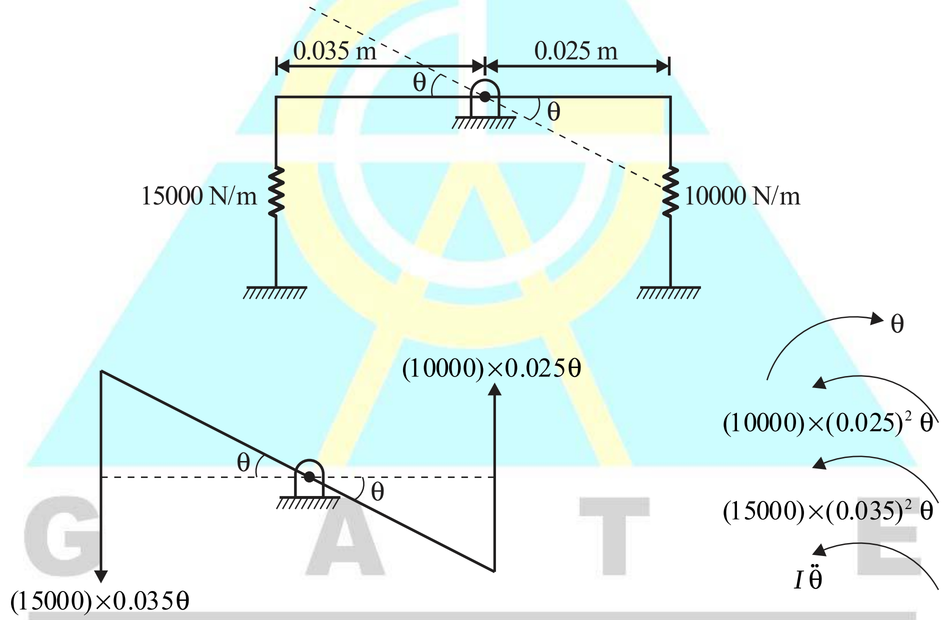
Resonance in the rocker system occurs when the cam shaft runs at a speed of _________ rpm (round off to the nearest integer).

Theory of Machine (CAM and Follower)

(A) 496 (B) 4739 (C) 2369 (D) 790

Ans. **B**

Sol.



$$I = 10^{-4} \text{ kg-m}^2$$

By D'Alembert Principle

$$I\ddot{\theta} + [10000\times(0.025)^2 + 15000\times(0.035)^2]\theta = 0$$

$$(10^{-4})\ddot{\theta} + (24.625)\theta = 0$$

$$\ddot{\theta} + \left(\frac{24.625}{10^{-4}}\right)\theta = 0$$

$\Rightarrow$ $$\omega_n^2 = 246250$$

$$\omega_n = 496.2358 \text{ rad/s}$$

$$N_C = \frac{496.2358 \times 60}{2\pi} = 4738.7031 \text{ rpm}$$

Question 48

Consider a binomial random variable *X*. If $X_1, X_2 ....., X_n$ are independent and identically distributed samples from the distribution of *X* with sum $Y = \sum_{i=1}^{n} X_i$, then the distribution of *Y* as $n \to \infty$ can be approximated as

Engineering Mathematics

(A) Normal (B) Bernoulli (C) Binomial (D) Exponential

Ans. A

Question 49

Let $f(x) = x^2 - 2x + 2$ be a continuous function defined on $x \in [1, 3]$. The point *x* at which the tangent of

$f(x)$ becomes parallel to the straight line joining $f(1)$ and $f(3)$ is

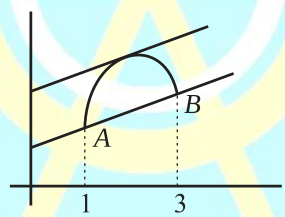
Engineering Mathematics

(A) 1 (B) 0 (C) 3 (D) 2

Ans. D

Sol. According to question, $f(x) = x^2 - 2x + 2$

$$f'(x) = \frac{f(b) - f(a)}{b - a}$$



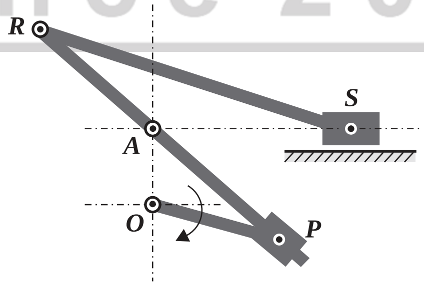
$$2x - 2 = \frac{5-1}{2}$$

$$2x - 2 = 2$$

$$x = 2$$

Question 50

The Whitworth quick return mechanism is shown in the figure with link lengths as follows: OP = 300 mm, OA = 150 mm, AR = 160 mm, RS = 450 mm.

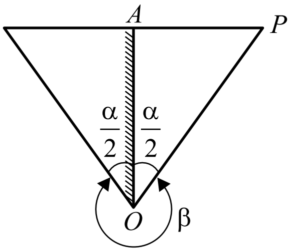


The quick return ratio for the mechanism is _____ (round off to one decimal place).

Theory of Machine (Quick Return Mechanism)

Ans. 2

Sol. **Given :** $OP = 300$ mm, $OA = 150$ mm, $AR = 160$ mm, $RS = 450$ mm



$$\cos\frac{\alpha}{2}=\frac{150}{300}=\frac{OA}{OP}$$

$$\alpha=60^0\times 2=120^0$$

$$\frac{\beta}{\alpha}=QRR$$

$$QRR=\frac{360-120}{120}=2$$

Question 51

An uninsulated cylindrical wire of radius 1.0 mm produces electric heating at the rate of 5.0 W/m. The temperature of the surface of the wire is 75^0C when placed in air at 25^0C. When the wire is coated with PVC of thickness 1.0 mm, the temperature of the surface of the wire reduces to 55^0C. Assuming that the heat generation rate from the wire and the convective heat transfer coefficient are same for both uninsulated wire and the coated wire. The thermal conductivity of PVC is ______ W/m.K (round off to two decimal places)

Heat Transfer (Conduction)

Ans. **0.1103**

Sol. **Given :** $Q_{gen}=5\ \text{W/m}$

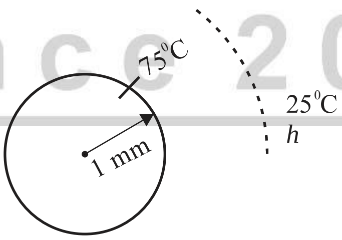
Temperature of air $=25^0\text{C}$

Temperature of wire surface when placed in air $=75^0\text{C}$

Thickness of PVC = 1 mm

After coating wire with PVC, final temperature $=55^0\text{C}$

Case 1 :



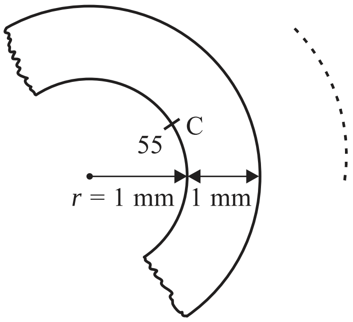
$$Q_{conv.}=hA_1\,\Delta T$$

$$Q_{gen}=Q_{conv} \quad\Rightarrow\quad 5=h\times A_1\,\Delta T \qquad (A_1=2\pi 0.001)$$

$$h=\frac{5}{2\times\pi\times 0.001\times(75^0-25^0)}$$

$$h=15.915\ \text{W/m}^2\text{K}$$

Case 2 :



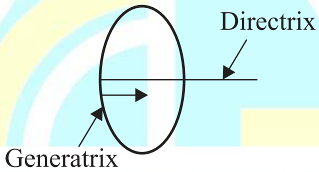
$$Q_{gen} = \frac{\Delta T}{\Sigma R_{th}} = \frac{55^0 - 25^0}{\frac{1}{2\pi K \times 1} \times \ln\left(\frac{2}{1}\right) + \frac{1}{15.915 \times 2\pi 0.002}} = 5\ \text{W/m}$$

On solving

$$K = 0.1103\ \text{W/mK}$$

Question 52

In a machining operation, if a cutting tool traces the workpiece such that directrix is perpendicular to the plane of the generatrix as shown in figure, the surface generated is



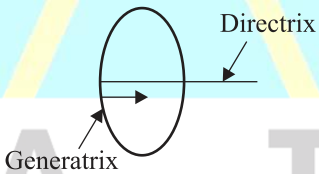
Production Engineering (Machining)

(A) spherical (B) cylindrical

(C) a surface of revolutions (D) plane

Ans. **B**

Sol.



Cylindrical surface generated.

Question 53

An orthogonal cutting operation is performed using a single point cutting tool with a rake angle of 12^0 on a lathe. During turning, the cutting force and the friction force are 1000 N & 600 N, respectively. If the chip thickness and the uncut chip thickness during turning are 1.5 mm and 0.75 mm, respectively, then the shear force is______N (round off to two decimal places)

Production Engineering (Machining)

Ans. **685.916**

Sol. **Given :** $\alpha = 12^0$

Cutting force, $F_C = 1000\ \text{N}$

Friction force, $F = 600\ \text{N}$

Chip thickness, $t_c = 1.5\ \text{mm}$

Uncut chip thickness, $t = 0.75$ mm

$$r = \frac{t}{t_c} = \frac{0.75}{1.5} = \frac{1}{2} = 0.5$$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

$$\phi = \tan^{-1}\left(\frac{0.5\cos(12)}{1-0.5\sin(12)}\right)$$

$$\phi = 28.62^0$$

Method 1 :

$$F = F_C \sin\alpha + F_T \cos\alpha$$

$$600 = 1000\sin(12) + F_T \cos(12)$$

$$F_T = 400.84 \text{ N}$$

$$F_S = F_C \cos\phi - F_T \sin\phi$$

$$F_S = 1000\cos(28.62) - 400.84\sin(28.62)$$

$$F_S = 685.81 \text{ N}$$

Method 2 :

$$F_C = R\cos(\beta - \alpha)$$

$$1000 = R\cos(\beta - 12^0) \quad \ldots \text{(i)}$$

and $$F = 600 = R\sin\beta \quad \ldots \text{(ii)}$$

Divide equation (i) and (ii),

$$\frac{1000}{600} = \frac{\cos(\beta - 12)}{\sin\beta}$$

$$= \frac{\cos\beta\cos(12) + \sin(12)\sin(\beta)}{\sin\beta}$$

$$\frac{1000}{600} = \cot\beta\cos(12) + \sin(12)$$

$$\beta = 33.84^0$$

So, $$F_s = R\cos(\phi + \beta - \alpha)$$

and $$R = \frac{F}{\sin\beta} = \frac{600}{\sin(33.84^0)}$$

$$R = 1077.43 \text{ N}$$

So, $$F_s = 1077.43\cos(28.62 + 33.84 - 12)$$

$$F_s = 685.916 \text{ N}$$

Question 54

Consider a single machine workstation to which jobs arrive according to a Poisson distribution with a mean arrival rate of 12 jobs/hour. The process time of the work station is exponentially distributed with a mean of 4 minutes. The expected number of jobs at the work station at any given point of time is_______ (round off to the nearest integer).

Industrial Engineering

Ans. 4

Sol. **Given :**

Arrival rate, $\lambda = 12$ Jobs/hour

Service rate, $\mu = 4$ minutes/customer

$$\mu = \frac{60}{4} = 15 \text{ Customer/hour}$$

$$\rho = \frac{\lambda}{\mu} = \frac{12}{15} = 0.8$$

$$L_S = \frac{\rho}{1-\rho} = \frac{0.8}{1-0.8} = \frac{0.8}{0.2} = 4 \text{ Customer}$$

Question 55

If $y(x)$ satisfies the differential equation

$$(\sin x)\frac{dy}{dx} + y\cos x = 1,$$

subjected to the condition $y(\pi/2) = \pi/2$, then $y(\pi/6)$ is

Engineering Mathematics (Differential Equations)

(A) $\pi/2$ (B) 0 (C) $\pi/6$ (D) $\pi/3$

Ans. D

Sol. Dividing the equation by sin$x$

$$\frac{dy}{dx} + y\cot x = \text{cosec}\, x$$

By integrating factor

$$IF = e^{\int \cot x dx} = e^{\log(\sin x)}$$

$$= \sin x$$

Now,

$$y \times \sin x = \int 1\, dx + c$$

$$y \sin x = x + c$$

$$y = x.\text{cosec}\, x + c.\text{cosec}\, x \quad \ldots(i)$$

By putting value in equation (i)

$$y\left(\frac{\pi}{2}\right) = \frac{\pi}{2}$$

$$\Rightarrow \quad \frac{\pi}{2} = \frac{\pi}{2} + 1 \times c$$

$$c = 0$$

Now, $y\left(\frac{\pi}{6}\right)$ is

$$y\left(\frac{\pi}{6}\right)=\frac{\pi}{6}\times\left(\text{cosec}\frac{\pi}{6}\right)+0$$

$$y\left(\frac{\pi}{6}\right)=\frac{\pi}{3}$$

Hence, the correct option is (D)

❖❖❖❖