GATE 2024

MECHANICAL ENGINEERING

Exam held on **03/02/2024** *(Afternoon Session)*

Memory based

Questions & Solutions

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SECTION - A GENERAL APTITUDE

Q.1 $\dfrac{x}{pq-r^2} = \dfrac{y}{qr-p^2} = \dfrac{z}{rp-q^2}$

given the denominator are non-zero, the value of $px + qy + rz$.

Ans. (0)

Let, $\dfrac{x}{pq-r^2} = \dfrac{y}{qr-p^2} = \dfrac{z}{rp-q^2} = K$

$$\frac{px}{p^2q-pr^2} = K$$

$$\frac{qy}{q^2r-qp^2} = K$$

$$\frac{rz}{r^2p-rq^2} = K$$

$$px + qy + rz = kp^2q - kpr^2 + kq^2r - kqp^2 + kr^2p - krq^2$$

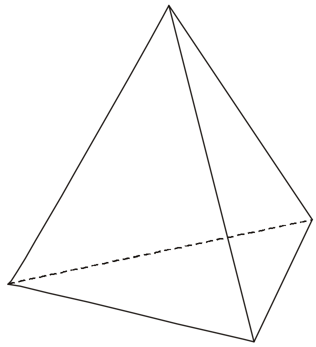
$$= 0$$

End of Solution

Q.2 Four equilateral triangles are used to form a regular closed three-dimensional object by joining the edges. The angle between any two faces is _______ degrees.

Ans. (60)

Tetrahedron Angles : In a regular tetrahedron, all the faces are equilateral triangles. Therefore, all the interior angles of a tetrahedron are 60° each.



End of Solution

Q.3 How many combinations of non-null sets A, B, C are possible from the subsets of Set $A = \{2, 3, 5\}$. Satisfying the condition.

1. B is subset of A.
2. C is subset of B.

Ans. (19)

Required combination $= 1 \times {}^3C_1 + 3 \times {}^3C_2 + 7 \times {}^3C_3$

$= 3 \times 1 + 3 \times 3 + 7 = 19$

End of Solution

Q.4 Find the odd one out in the set

11, 17, 19, 21, 23, 29, 31, 37

Ans. (21)

Except 21 all are prime number.

End of Solution

Q.5 Find the odd one/wrong one from the given series

0, 1, 1, 2, 3, 6, 8, 13, 21

Ans. (6)

$0 + 1 = 1$

$1 + 1 = 2$

$2 + 1 = 3$

$2 + 3 \neq 6$

$3 + 5 = 8$

$5 + 8 = 13$

$8 + 13 = 21$

End of Solution

SECTION - B TECHNICAL

Q.6 The value of surface integral $\oiint_S z\,dx\,dy$ where S is the external surface of the sphere $x^2 + y^2 + z^2 = R^2$ is

(a) 0
(b) $\frac{4\pi}{3}R^3$
(c) πR^3
(d) $4\pi R^3$

Ans. (b)

$\oiint_S z\,dx\,dy$

where $S(\text{sphere}) = x^2 + y^2 + z^2 = R^2$

$$= \oiint z\,dx\,dy \Rightarrow \text{it represent the volume of sphere}$$

$$= \frac{4}{3}\pi R^3$$

End of Solution

Q.7 If the value of double integral

$\int_{x=3}^{4}\int_{y=1}^{2} \frac{dy\,dx}{(x+y)^2}$ is $\log_e\left(\frac{a}{24}\right)$, then a is ________.

Ans. (25)

Given, $\int_{x=3}^{x=4}\int_{y=1}^{y=2} \frac{dx\,dy}{(x+y)^2}$

$$= \int_{x=3}^{x=4} -\left[\frac{1}{(x+y)}dx\right]_{y=1}^{y=2} = -\int_{x=3}^{x=4}\left[\frac{1}{2+x} - \frac{1}{x+1}\right]$$

$$= -[\ln(2+x) - \ln(x+1)]_{x=3}^{x=4}$$

$$= -\left[\ln\left(\frac{2+x}{x+1}\right)\right]_3^4 = -\left[\ln\left(\frac{6}{5}\right) - \ln\left(\frac{5}{4}\right)\right]$$

$$= -\left[\ln\left(\frac{6\times 4}{5\times 5}\right)\right] = -\ln\left(\frac{24}{25}\right)$$

$$= \ln\left(\frac{25}{24}\right)$$

Given, $\ln\left(\frac{a}{24}\right)$

$\therefore\ a = 25$

End of Solution

Q.8 If $x(t)$ satisfies the differential equation $t\frac{dx}{dt}+(t-x)=0$.
Subject to the condition $x(1) = 0$ then the value of $x(2)$ is ________.

Ans. (–1.386)

$$t\frac{dx}{dt}+t-x = 0$$

$$\frac{dx}{dt}-\frac{x}{t}+1 = 0$$

$$\frac{dx}{dt}-\frac{1}{t}x = 1$$

Compare it $\quad \frac{dx}{dt}+Px = Q$

$$P = \frac{-1}{t} \quad Q = -1$$

$$\text{IF} = e^{\int -\frac{1}{t}dx} = e^{\ln t} = e^{\ln\left(\frac{1}{t}\right)} = \frac{1}{t}$$

$$x\cdot\frac{1}{t} = \int -1\cdot\frac{1}{t}dt + c$$

$$\frac{x}{t} = -\ln t + c \Rightarrow \frac{x}{t} = \ln\left(\frac{1}{t}\right)+c$$

$$\frac{x}{t} = \ln\frac{1}{t}+c \Rightarrow x = t\cdot\ln\frac{1}{t}+ct$$

Boundary condition, $x(1) = 0$
at $t = 1$, $x = 0$

$$0 = 0 + c \Rightarrow c = 0$$

Now, $\quad x = t\cdot\ln\frac{1}{t}$

at $t = 2$

$$x = 2\ln\frac{1}{2} \; ; \quad x = -2\ln 2$$

$$x = -2 \times 0.693 = -1.386$$

End of Solution

Q.9 Let $f(z)$ be an analytic function, where $z = x + iy$. If the real part of $f(z)$ is $\cosh x \cos y$, and the imaginary part of $f(z)$ is zero for $y = 0$, then $f(z)$ is

(a) $\cosh z$
(b) $\cosh x\ e^{-iy}$
(c) $\cosh z\ e^{z}$
(d) $\cosh z \cos y$

Ans. (a)

$$f(z) = u + iv$$

$$u = \cosh z \cos y$$

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

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

by Milne Thomson method

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

Partial differentiate w.r.t. x, y

$$u_x = \left(\frac{e^x - e^{-x}}{2}\right)\cos y; \qquad u_y = \left(\frac{e^x + e^{-x}}{2}\right)(-\sin y)$$

$$u_x = \left(\frac{e^x - e^{-x}}{2}\right)\cos y \qquad u_y = -\frac{(e^x + e^{-x})}{2}\sin y$$

$$u_x(z, 0) = \frac{e^z - e^{-z}}{2} = \sinh z \qquad u_y(z, 0) = -0$$

$$f(z) = \int (u_x - iu_y)dz + c$$

$$= \int (\sinh z - a)dz + c$$

$$= \int \sinh z + c$$

$$= \cosh z + c$$

End of Solution

Q.10 The matrix $\begin{bmatrix} 1 & \alpha \\ 8 & 3 \end{bmatrix}$ where $\alpha > 0$ has a negative eigen value if α is greater than

(a) $\frac{1}{8}$

(b) $\frac{1}{4}$

(c) $\frac{3}{8}$

(d) $\frac{1}{5}$

Ans. **(c)**

Characteristic equation

$$\lambda^2 - 4\lambda + (3 - 8\alpha) = 0$$

$$\lambda = \frac{4 \pm \sqrt{16 - 4(3 - 8\alpha)}}{2} = \frac{4 \pm \sqrt{4 + 32\alpha}}{2}$$

For negative eigen value

$$\sqrt{4 + 32\alpha} > 4$$

$$4 + 32\alpha > 16$$

$$32\alpha > 12$$

$$\alpha > \frac{3}{8}$$

End of Solution

Q.11 Let X be a continuous random variable defined on [0, 1] such that its probability density function

$$f(x) = 1 \quad ; \quad 0 \le x \le 1$$
$$= 0 \quad ; \quad \text{otherwise}$$

If $y = \log_e(X + 1)$, then the expected value of y is

Ans. (–1)

$$f(x) = \begin{cases} 1 & 0 \le x \le 1 \\ 0 & \text{otherwise} \end{cases} \qquad y = \ln(x+1)$$

$$E[Y] = \int_{-\infty}^{\infty} Y \cdot f(x)$$

$$= \int_0^1 1 \cdot \ln(x+1)dx = \int_0^1 \ln(x+1)dx = \int_0^1 \ln(x+1)$$

$$= \int_1^2 \ln t\, dt \qquad \left[\begin{array}{l} \because x+1 = t \\ \therefore dx = dt \end{array}\right]$$

$$= [t \cdot \ln t - t]_1^2 = (2\ln 2 - 2) - (1\ln 1 - 1)$$

$$= -0.6137 + 1$$

$$= 0.3863$$

End of Solution

Q.12 Consider the system of linear equation:

$x + 2y + z = 5$

$2x + ay + 4z = 12$

$2x + 4y + 6z = b$

The value of a and b such that there exist a infinitely many solutions.

Ans. (14)

$$x + 2y + z = 5$$
$$2x + ay + 4z = 12$$
$$2x + 4y + 6z = b$$

$$\left|\begin{array}{ccc|c} 1 & 2 & 1 & 5 \\ 2 & a & 4 & 12 \\ 2 & 4 & 6 & b \end{array}\right| \xrightarrow[R_3 = R_2 - 2R_1]{R_2 = R_2 - 2R_1} \left[\begin{array}{ccc|c} 1 & 2 & 1 & 5 \\ 0 & 0-4 & 2 & 2 \\ 0 & 0 & 4 & b-10 \end{array}\right]$$

$$\rho(A) = 2$$

For Rank of $A = 2$

$$a - 4 = 0$$
$$a = 4$$

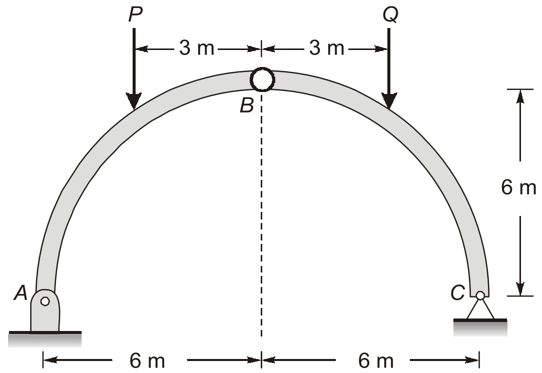
and $\rho(AB) = 2$

for this $R_3 = 2R_2$

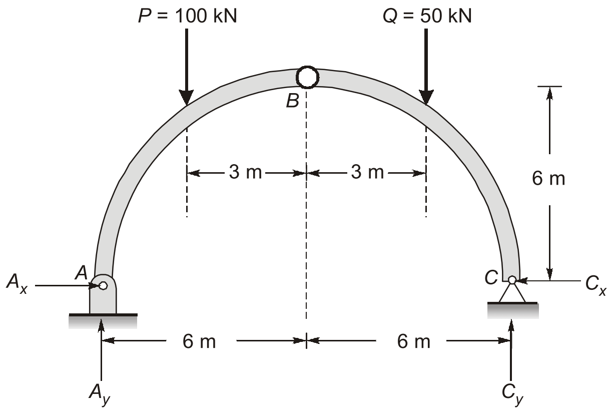
$$b - 10 = 4$$
$$b = 14$$

End of Solution

Q.13 A three-hinge arch ABC in the form of a semi-circle is shown in the figure. The arch is in static equilibrium under vertical loads P = 10 kN and Q = 50 kN. Neglect friction at all the hinges. The magnitude of horizontal reaction at B is____kN. [Correct upto 1 decimal place]



Ans. (37.5)



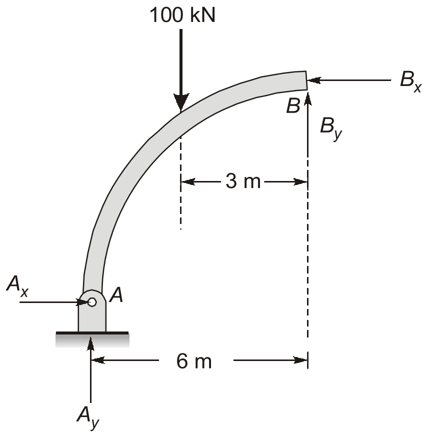
Initially, taking moment about hinged point C.

$\Sigma M_C = 0$

$A_y \times 12 - 100 \times 9 - 50 \times 3 = 0$

$\Rightarrow \qquad A_y = 87.5$ kN

FBD for left half section:



Now taking moment about point B.

$\Sigma M_B = 0$

$A_x \times 6 - 87.5 \times 6 + 100 \times 3 = 0$

$\Rightarrow \quad A_x = 37.5 \text{ kN}$

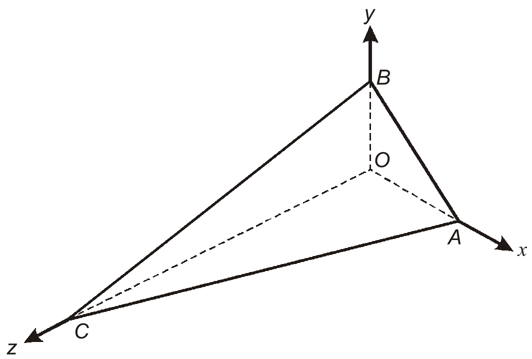
$\Sigma F_x = 0$

$A_x - B_x = 0$

$\Rightarrow \quad B_x = A_x = 37.5 \text{ kN}$

End of Solution

Q.14 A rigid massless tetrahedron is placed such that vertex O is at the origin and the other three vertices A, B and C lies on the co-ordinate axes as shown in the figure. The body is acted on by three point loads of which one is acting at A along x-axis and the other at point B along y-axis. For the body to be in equilibrium, the third point load acting at point O must be



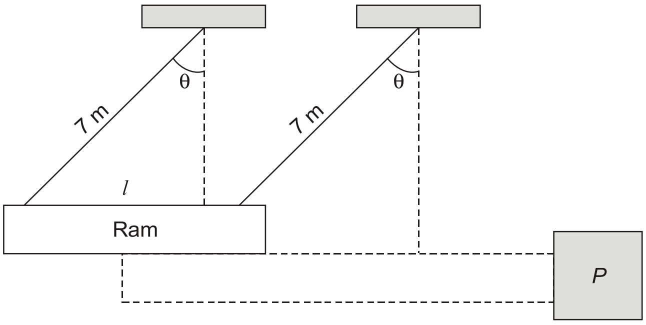
(a) in *z-x* plane but not along *z* or *x*-axis
(b) in *x-y* plane but not along *x* or *y*-axis
(c) in *y-z* plane but not along *y* or *z*-axis
(d) along z-axis

Ans. (d)

For the body to be in equilibrium, all three forces must be concurrent. Hence, the third point load acting at point 'O' must be along *z*-axis.

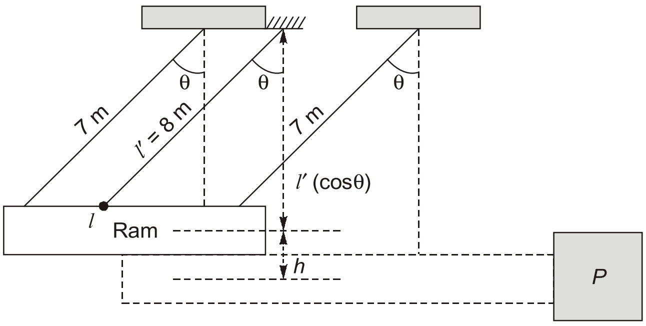
End of Solution

Q.15 A ram in the form of a rotating body of size $l = 9$ m and $b = 2$ m is suspended by two parallel ropes of lengths 7 m. Assume the centre of mass of the body is at its geometric centre and $g = 9.81 \text{ m/s}^2$. For striking the object P with with horizontal velocity of 5 m/s, what is the angle θ with the vertical from which the ram should be released from rest?



(a) 79.5°
(b) 40.2°
(c) 35.1°
(d) 67.1°

Ans. (c)



Refer figure, $l' = 8$ m

$\therefore \quad h = l'(1 - \cos\theta)$

Now, by energy balance,

$$mgh = \frac{1}{2}mV^2 \qquad [\because \text{PE} = \text{KE}]$$

or $$9.81 \times 8(1 - \cos\theta) = \frac{1}{2}\times 25$$

On solving, we get $\theta = 32.78°$

Note: If we take $l' = 7$ m, and solving as above, then we will get $\theta = 35.1°$. Hence option (C) is correct.

End of Solution

Q.16 The velocity field of a two-dimensional, incompressible flow is given by $\vec{V} = 2\sinh x\,\hat{i} + V(x,y)\hat{j}$ where $\hat{i}$ and $\hat{j}$ denote the unit vectors in x and y direction, respectively. If $V(x, 0) = \cosh x$, then $V(0, -1)$ is

(a) 1
(b) 2
(c) 3
(d) 4

Ans. (c)

The velocity field of a two-dimensional, incomplete flow is given by,

$$\vec{V} = 2\sinh x\,\hat{i} + V(x,y)\hat{j}$$

and $V(x, 0) = \cosh x,$

For an incomplete flow, $\nabla \cdot \vec{V} = 0$

$$\Rightarrow \quad \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$2\cosh x + \frac{\partial v}{\partial y} = 0$$

$$\Rightarrow \quad \frac{\partial v}{\partial y} = -2\cosh x$$

$$\Rightarrow \quad \int \partial v = \int -2\cosh x \cdot \partial y$$

$$V = -2y \cdot \cosh x + f(x)$$

For, $V(x, 0) = \cosh x$

$$\Rightarrow \quad -2y \cdot \cosh x + f(x) = \cosh x$$

$$\Rightarrow \quad f(x) = \cosh x$$

$$\Rightarrow \quad V = -2 \cdot y \cdot \cosh x + \cosh x$$

$$V = (1 - 2y)\cosh x$$

$$V(0, -1) = [1 - 2 \times (-1)] \times \cosh(0)$$

$$= 3$$

End of Solution

Q.17 Find the value of 'a' where $L = k\gamma^a R^b \mu^c \sqrt{t}$.

Ans. (0.5)

Dimension of surface tension = $[MT^{-2}]$

Dimension of radius = [L]

Dimension of dynamic viscosity = $[ML^{-1}T^{-1}]$

Dimension of time = [T]

Now, $L = k\gamma^a R^b \mu^c \sqrt{t}$

$$\Rightarrow \quad [L] = \left[M^0L^0T^0\right]\left[MT^{-2}\right]^a [L]^b \left[ML^{-1}T^{-1}\right]^c [T]^{1/2}$$

$$\Rightarrow \quad a + c = 0 \quad \text{...(i)}$$

$$\Rightarrow \quad b - c = 1 \quad \text{...(ii)}$$

$$-2a - c + \frac{1}{2} = 0 \quad \text{...(iii)}$$

On solving equation (i), (ii) and (iii), we get

$$a = 0.5,\ b = 0.5 \text{ and } c = -0.5$$

End of Solution

Q.18 Sequence for minimised span

U	V	W	X	Y	Z	Job
5	7	3	4	6	8	Workstation 1
4	6	6	8	5	7	Workstation 2

(a) WUZUYX (b) WXVZYU
(c) WXZVYU (d) UYVZXW

Ans. (b)

As per Johnson's algorithm the optimum sequence is

W - X - V - Z - Y - U

Hence, correct option is (b).

End of Solution

Q.19 In a workstation with single server, the job arrive at 5 jobs per hour and service rate is 6 minutes per job. What is the probability that the system is idle?

Ans. (0.5)

Given: $\lambda = 5/\text{hr}$, $\mu = 10/\text{hr}$

$$\therefore \quad \rho = \frac{\lambda}{\mu} = \frac{5}{10} = \frac{1}{2}$$

Now, probability for the system to be idle,

$$P_o = 1 - \rho = 1 - 0.5 = 0.5 \qquad \text{Ans.}$$

End of Solution

Q.20 Given : D = 8000 units/year, C_0 = ₹300 per order, C_h = ₹12 per unit per month. If Q = 1.25 times of EOQ, then percentage increase in inventory cost is ____.

Ans. (2.5)

Given: D = 8000 units/yr, C_o = Rs. 300/order, C_h = Rs. 12 × 12 = Rs. 144 per year

Now, $$\text{EOQ} = \sqrt{\frac{2C_oD}{C_h}} = \sqrt{\frac{2\times 300\times 8000}{144}}$$

$$\therefore \quad Q^* = 182.5 \text{ units}$$

Now, Actual quantity, $Q = 1.25Q^* = 1.25 \times 182.5$
$= 228.125$ units

Total cost at EOQ, $$\text{TIC}_1 = \sqrt{2C_oC_hD} = \sqrt{2\times 300\times 144\times 8000}$$
$= \text{Rs. } 26290.68$

Now, Total cost at Q = 228.125 units,

$$\text{TIC}_2 = \frac{Q}{2}\times C_h + \frac{D}{Q}\times C_o$$

$$= \frac{228.125}{2}\times 144 + \frac{8000}{228.125}\times 300$$

$= \text{Rs. } 26945.54$

$$\therefore \quad \%\text{ increase} = \frac{26945.54 - 26290.68}{26290.68}\times 100 = 2.5\%$$

Alternative solution

We know, if $Q = kQ^*$

then, $$\frac{TIC(Q)}{TIC(Q^*)} = \frac{1}{2}\left[k + \frac{1}{k}\right]$$

∴ Percentage increase,

$$\frac{TIC(Q) - TIC(Q^*)}{TIC(Q^*)} \times 100 = \left(\frac{TIC(Q)}{TIC(Q^*)} - 1\right) \times 100$$

$$= \left(\frac{1}{2}\left[k + \frac{1}{k}\right] - 1\right) \times 100$$

$$= \left(\frac{1}{2}\left[1.25 + \frac{1}{1.25}\right] - 1\right) \times 100$$

$= 0.025 \times 100$

$= 2.5\%$

End of Solution

Q.21 The optimal cost of satisfying the total demand from all retailers is ________.

Supplier \ Retailer	1	2	3	4	Capacity
A	11	16	19	13	300
B	5	10	7	8	300
C	12	14	17	11	300
D	8	15	11	9	300
Demand	300	300	300	300	

Ans. (12300)

As per Hungarian method, subtracting the smallest value from each column from other elements of that column, we get

6	6	12	5
0	0	0	0
7	4	10	3
3	5	4	1

Similarly, for each row, we get the following matrix.

1	1	7	0
0	0	0	0
4	1	7	0
2	4	3	0

Since, the minimum number of lines to cover each zero of every row and column is less than the order of matrix. So to get the opportunity matrix, we will subtract smallest value from every element without lines and adding the same at intersection we will get the following matrix.

0	0	6	0
0	0	0	0
3	0	6	0
1	3	2	0

Since the minimum number of lines is equal to the order of matrix. Assignment can be done in the matrix as shown below.

[0]	0	6	~~0~~
~~0~~	~~0~~	[0]	0
3	[0]	6	~~0~~
1	3	2	[0]

So, optimal solution is

$= (11 + 7 + 14 + 9) \times 300$

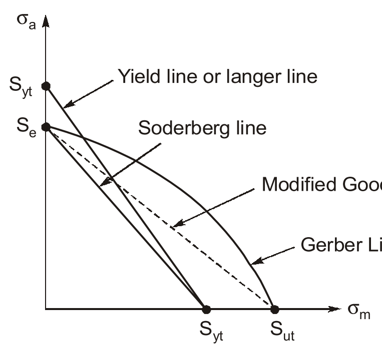
$= ₹12300$

End of Solution

Q.22 Which one of the following failure theories is the most conservative design approach against fatigue failure?

(a) Soderberg line
(b) Yield line
(c) Gerber line
(d) Modified Goodman line

Ans. (a)



Soderberg line is the most conservative fatigue failure criterion.

End of Solution

Q.23 For a ball bearing, the fatigue life in million revolutions is given by $L = \left(\frac{C}{P}\right)^n$ where P is the constant applied load and C is the basic dynamic load rating.

Which one of the following statements is true?

(a) n = 3, assuming that the inner race is fixed and outer race is revolving
(b) n = 1/3, assuming that the outer race is fixed and inner race is revolving
(c) n = 1/3, assuming that the inner race is fixed and outer race is revolving
(d) n = 3, assuming that the outer race is fixed and inner race is revolving

Ans. (d)

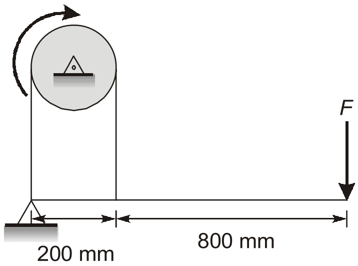
- For a ball bearing, the fatigue life in million revolution is given by,

$$L_{90} = \left[\frac{C}{P}\right]^3$$

- In case of axle, the inner race is fixed and outer race is revolving.
- In case of shaft, the outer race is fixed and inner race is revolving.

End of Solution

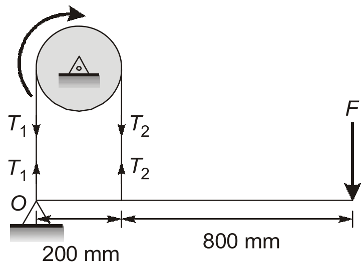
Q.24 A band brake shown in figure below has a coefficient of friction of 0.3. The band can take a maximum force of 1.5 kN. The maximum bending force (F) that can be safely applied is_____N. [Answer in integer]



Ans. (117)

Given: $\mu = 0.3$, $T_1 = 1.5$ kN

Taking moment about hinge point O.



$\Sigma M_o = 0$

$\Rightarrow F \times 1000 - T_2 \times 200 = 0$

$$\Rightarrow \quad F = \frac{T_2 \times 200}{1000} \quad \dots \text{(i)}$$

Also,
$$\frac{T_1}{T_2} = e^{\mu\theta} \Rightarrow \frac{1.5}{T_2} = e^{0.3\times\pi}$$

$$\Rightarrow \quad T_2 = \frac{1.5 \times 1000}{e^{0.3\times\pi}} = 584.49 \text{ N}$$

From equation (i), we have

$$F = \frac{200 \times 584.49}{1000} = 116.89 \text{ N} \simeq 117 \text{ N}$$

End of Solution

Q.25 Allowance provided to a pattern for easy withdrawal from sand mold

(a) Shrinkage allowance
(b) Distortion allowance
(c) Shake allowance
(d) Finishing allowance

Ans. (c)

Shake allowance is also known as rapping allowance. Before the withdrawal from the sand mould, the pattern is rapped/shaken all around the vertical faces to enlarge the mould cavity slightly, which facilitates its easy removal.

End of Solution

Q.26 In arc welding process, $V = 30$ V, $I = 200$ A, cross-sectional area of point 20 mm^2. Welding speed 5 mm/s. Heat required to melt the material is 20 J/s. The percentage of heat lost surrounding during welding process is _____.

Ans. (*)

Given : $V = 30$ V; $I = 200$ Amp, $A_c = 20$ mm^2, $v = 5$ mm/sec

Assuming, $H_{req} = 20$ J/s

Heat required to melt $(H_m) = 20$ J/s

$$\text{Heat lost to surrounding} = \left(\frac{H_s - H_m}{H_s}\right) \times 100$$

$$\text{Heat supplied } (H_s) = \frac{VI}{v}\eta_h = \frac{30 \times 200}{5} \times 1 = 1200 \text{ J/s}$$

$$\text{Heat lost} = \left(\frac{1200 - 20}{1200}\right) \times 100 = 98.33\%$$

Assuming, heat required to melt $(H_m) = 20$ J/mm^3

$$\text{Heat supplied } (H_s) = \frac{VI}{v \times A}\eta_h = \frac{30 \times 200}{5 \times 20} \times 1 = 60 \text{ J/mm}^3$$

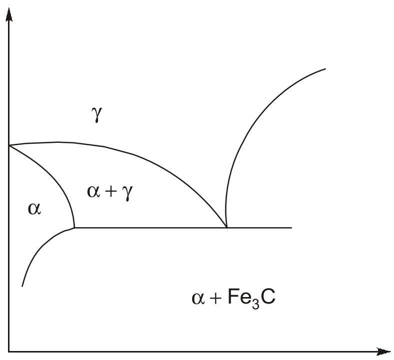
$$\text{Heat lost} = \left(\frac{60 - 20}{60}\right) \times 100 = 66.67\%$$

End of Solution

Q.27 Pearlite consists of

(a) Austenite and Cementite
(b) Ferrite and Cementite
(c) Austenite and Martensite
(d) Martensite and Pearlite

Ans. (b)



End of Solution

Q.28 A cutting tool provides a tool life of 60 minutes while machining with a cutting speed of 60 m/min when same tool used for machining same material, provides tool life of 10 mins for cutting speed 100 m/min. If cutting speed is changed to 80 m/min for same tool and work material combination, tool life computed using Taylor's tool life model is _____ minutes.

Ans. **(21.87)**

Given : $V_1 = 60$ m/min; $V_2 = 100$ m/min; $V_3 = 80$ m/min

$T_1 = 60$ min; $T_2 = 10$ min; $T_3 = ?$

By using Taylor's equation,

$$V_1 T_1^n = V_2 T_2^n$$

$$\Rightarrow \quad 60 \times (60)^n = 100 \times (10)^n$$

$$\Rightarrow \quad \left(\frac{60}{10}\right)^n = \frac{100}{60} \Rightarrow n = \frac{\ln\left(\frac{100}{60}\right)}{\ln\left(\frac{60}{10}\right)} = 0.285$$

Also, $$V_1 T_1^n = V_3 T_3^n$$

$$\Rightarrow \quad 60 \times (60)^{0.285} = 80 \times (T_3)^{0.285}$$

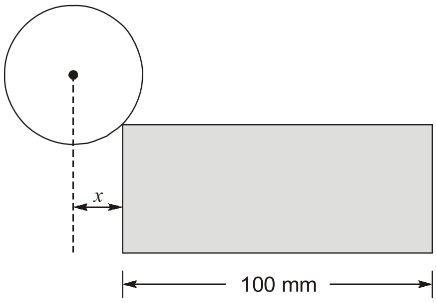
$$\Rightarrow \quad T_3 = 21.87 \text{ min.}$$

End of Solution

Q.29 A flat surface of C60 steel 100 mm length × 200 mm width is produced by HSS slab mill 8 toothed cutter has 100 mm (diameter) and 200 mm (width). Feed per tooth 0.1 mm cutting velocity 20 m/min, depth of cut is 2 mm. The machining time required to remove the entire stock is _____ minutes.

Ans. **(2.24)**

Given: $L \times B = 100$ mm × 200 mm, $Z = 8$, $D = 100$ mm, $W = 200$ mm, $f_t = 0.1$ mm/tooth, $V = 20$ m/min, $d = 2$ mm



Approach length, $x = \sqrt{d(D-d)} = \sqrt{2\times(100-2)} = 14\text{ mm}$

∴ The effective length, $L_e = L + x = 100 + 14 = 114$ mm

$$N = \frac{V\times 1000}{\pi \times D} = \frac{20\times 1000}{\pi\times 100} = 63.662\text{ rpm}$$

$$F = f_t \times NZ = 0.1 \times 63.662 \times 8 = 50.93\text{ mm/min}$$

∴ The machining time required to remove the entire stock;

$$t_{m/c} = \frac{L_e}{F} = \frac{114}{50.93} = 2.238 \text{ minutes}$$

$$\simeq 2.24 \text{ minutes}$$

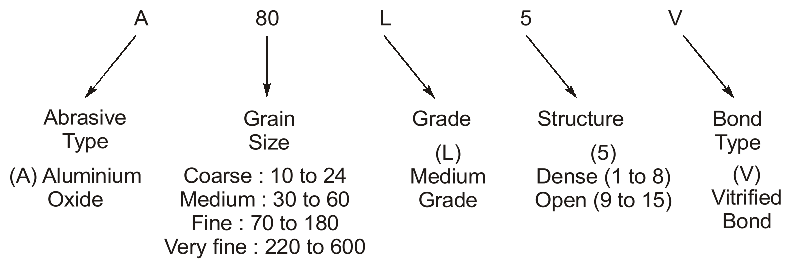
End of Solution

Q.30 Grinding wheel used to provide best surface finish

(a) A80L5V
(b) A36L5V
(c) A54L5V
(d) A60L5V

Ans. **(a)**

In grinding operation, surface finish is decided by the grain size. Fine and very fine grain size will result in best surface finish.



End of Solution

Q.31 Preparatory functions of CNC programming is denoted by

(a) G
(b) O
(c) M
(d) P

Ans. **(a)**

Preparatory function of CNC programming is denoted by G-codes. Preparatory functions are the G-codes that identify the type of activities the machine will execute. The preparatory functions describe the way in which the machine axes have to move, the method of interpolation, the dimension system, the time delay of program execution and the activation of specific operational modes in the control.

End of Solution

Q.32 Most suitable electrode for gas metal arc welding for joining low alloy steels is

(a) Cd
(b) W
(c) Cu
(d) Low alloy steels

Ans. **(d)**

In GMAW, consumable electrodes are used which has to be same composition as base metal.

End of Solution

Q.33 A blanking operation is performed on C20 steel sheet to obtain a circular disc having diameter of 20 mm and thickness 2 mm. Allowance of 0.04 is provided. The punch size used in operation is ______ mm.

Ans. (19.96)

Diameter of blank = 20 mm

Allowance, 2C = 0.04 mm

Blank size = Die size = 20 mm

Punch size = Die size − 2 × C

= 20 − 0.04 = 19.96 mm

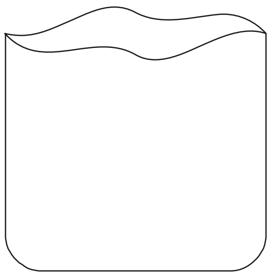
End of Solution

Q.34 Earing defect is associated with which of the following processes?

(a) Deep drawing
(b) Rolling
(c) Forging
(d) Extrusion

Ans. (a)

Anisotropy plays an important role in the performance of deep drawing processes. The anisotropy is of two types. In normal anisotropy the properties differ in the thickness direction. In planar anisotropy, the properties vary with the orientation in the plane of the sheet. Whereas deep drawability of sheets increases with normal anisotropy, anisotropy leads to the formation of ears in cup drawing. Ears cause the wavy edge of a drawn cup



An earing defect showing the formation of ears

End of Solution

Q.35 Aluminium is casted in a cube-shaped mold having dimensions as 20 mm × 20 mm × 20 mm. Another mold of same material is used to cast a sphere of Aluminium having diameter 20 mm, Pouring temperature is same, ratio of solidification times of cube shaped mold to the spherical mold is ______. [Answer in Integer]

Ans. (1)

Given: Cube shaped mould = 20 mm × 20 mm × 20 mm

Sphere shaped mould, D = 20 mm

By Chvorinov's rule:

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

$$\frac{(t_B)_c}{(t_s)_{sp}} = \frac{(V/A)^2}{(V/A)^2_{sp}} = \frac{(a^3/6a^2)^2}{\left(\dfrac{\frac{\pi D^3}{6}}{\pi D^2}\right)^2}$$

$$= \frac{(a/6)^2}{(D/6)^2} = 1 \qquad [\because\ a = D = 20 \text{ mm}]$$

End of Solution

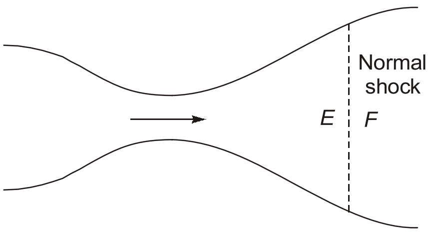
Q.36 Which one of the following is NOT correct regarding Rankine cycle?
(a) Superheating in boiler increases the cycle efficiency.
(b) decrease in boiler pressure, increases the efficiency of Rankine cycle.
(c) decrease in condensor pressure, increases the efficiency of Rankine cycle.
(d) The pressure of turbine outlet is governed by the condensor temperature.

Ans. (b)

- Superheating is Rankine cycle increases the cycle efficiency because of increase in mean temperature of heat addition.
- With increase in pressure of boiler, increases the efficiency of Rankine cycle. So, the given statement is wrong.
- With decrease in condensor pressure, increases the efficiency of Rankine cycle because of decrease in mean temperature of heat rejection.
- The pressure of turbine outlet is governed by the condensor temperature. Decreasing the cooling water temperature, creates more vacuum in condensor which results in pressure drop and vice-versa.

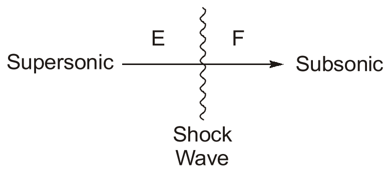
End of Solution

Q.37 Consider a compressible flow in a converging diverging nozzle as following:



Which of the following is correct?
(a) $\rho_E < \rho_F$
(b) $P_E < P_F$
(c) $M_E > M_F$
(d) Specific gravity at E < Specific gravity at F

Ans. (a, b, c)



After normal shock:

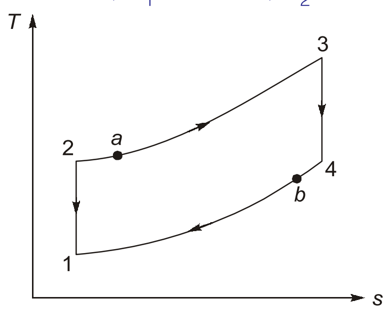
- Stagnation temperature remains the same.
- Density after shock will increase, i.e., $\rho_E < \rho_F$.
- Mach number will decrease, i.e., $M_E > M_F$.
- Specific gravity will decrease, i.e., $S_E < S_F$.

End of Solution

Q.38 For a gas turbine plant working on ideal brayton cycle with regeneration, the temperatures at various stages are given as:
Temperature at entry of compressor = 300 K
Temperature at exit of compressor = 550 K
Maximum temperature in the cycle = 1200 K
Temperature at exit of turbine = 800 K
The compressed air is heated upto 750 K using the exhaust gases from turbine and exhaust gas exit temperature is 600 K. The thermal efficiency of the cycle will be _____%.

Ans. (25)

Given: $T_a = 750$ K, $T_b = 600$ K, $T_1 = 300$ K, $T_2 = 550$ K, $T_3 = 1200$ K, $T_4 = 800$ K.

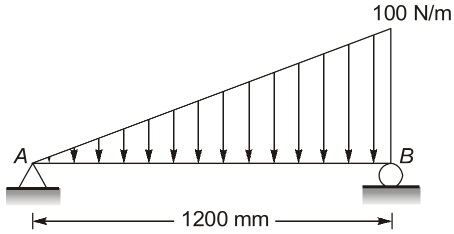


Now,
$$\eta = 1 - \frac{Q_R}{Q_s} = 1 - \frac{(T_b - T_1)}{(T_3 - T_a)} = 1 - \frac{(600 - 300)}{(1200 - 750)}$$

$$\eta = 1 - \frac{300}{400} = 25\%$$

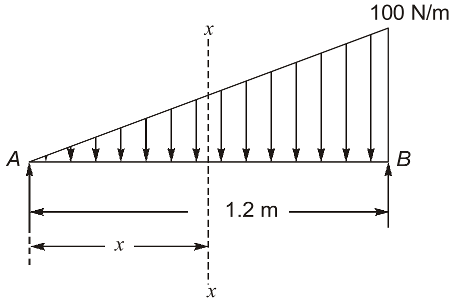
End of Solution

Q.39 A horizontal beam of length 1200 mm is pinned at the left end and is resting on a roller at the other end as shown in the figure below. A linearly varying distributed load is applied on the beam. The magnitude of maximum bending moment applied on the beam is ____Nm. [Correct upto 1 decimal place]



Ans. (9.237)

Reactions at the ends,



$$R_A + R_B = \frac{1}{2} \times 1.2 \times 100$$

$\therefore$ $$R_A + R_B = 60 \text{ N} \quad \dots \text{(i)}$$

$\Sigma M_B = 0$

$\therefore$ $$R_A \times 1.2 = \left(\frac{1}{2} \times 1.2 \times 100\right) \times \frac{1.2}{3}$$

$\therefore$ $$R_A = 20 \text{ N}$$

$\therefore$ $$R_B = 40 \text{ N}$$

Now, SF at section 'x' from 'A'

$SF_x = 0$

$\therefore$ $$20 - \frac{1}{2} \times x \times \frac{100x}{1.2} = 0$$

$\therefore$ $$x = 0.693 \text{ m}$$

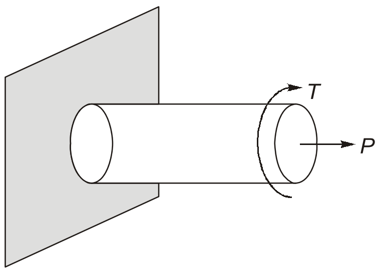
$\therefore$ At x = 0.693, BM will be maximum,

$\therefore$ $$M_{max} = 20 \times 0.693 - \frac{1}{2} \times \frac{0.693 \times 100 \times 0.693}{1.2} \times \frac{0.693}{3}$$

$\therefore$ $$M_{max} = 9.237 \text{ N-m}$$

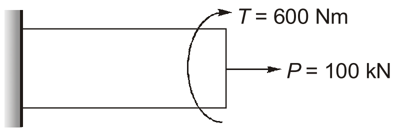
End of Solution

Q.40 A solid massless cylindrical member of 50 mm diameter is rigidly attached at one end and is subjected to an axial force P = 100 kN and a toque T = 600 Nm at the other end as shown. Assume that the axis of the cylinder is normal to the support. Considering distortion energy theory with allowable yield stress as 300 MPa, the FOS in the design is____. [Correct upto 1 decimal place]



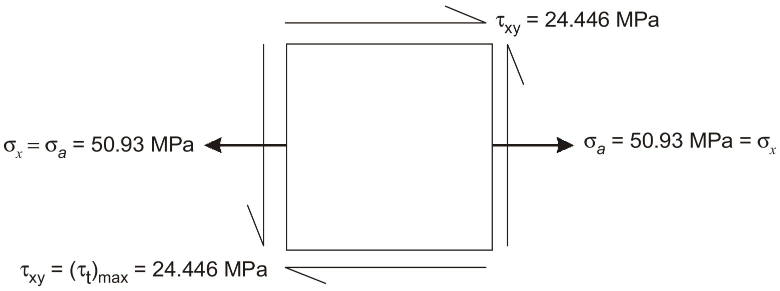
Ans. (4.5)

Given : D = 50 mm; S_{yt} = 300 MPa



Axial stress due to P, $\sigma_x = \sigma_a = \dfrac{P}{A} = \dfrac{100 \times 10^3}{\left(\dfrac{\pi \times 50^2}{4}\right)} = 50.93$ MPa

Shear stress due to T, $\tau_{xy} = (\tau_t)_{max} = \dfrac{16 \times T}{\pi D^3} = \dfrac{16 \times 600 \times 10^3}{\pi \times 50^3} = 24.446$ MPa



$$\sigma_y = 0$$

$$(\sigma_t)_{per} \geq \sqrt{\sigma_x^2 + 3\tau_{xy}^2}$$

$$\frac{S_{yt}}{N} = \frac{300}{N} \geq \sqrt{50.93^2 + 3 \times 24.446^2}$$

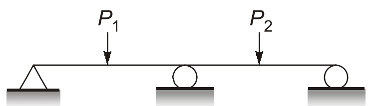
$$N \leq \frac{300}{66.232}$$

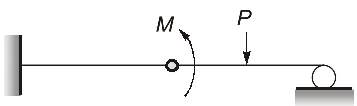
$$N \leq 4.529$$

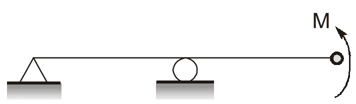
$$N = 4.5$$

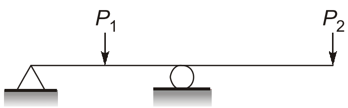
End of Solution

Q.41 Which of the following beam(s) is/are statically indeterminate?

(a)


(b)


(c)


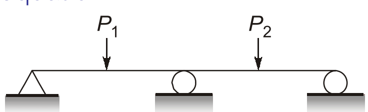
(d)


Ans. (a)

Statically indeterminate structures those structure that cannot be analyzed using statics or equations of equilibrium. In this case the number unknowns exceeds the number of equilibrium equation available.

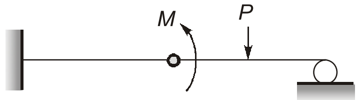
Number of unknown = 3

Number of equilibrium equation = 2



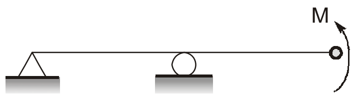
Number of unknown = 3

Number of equilibrium equation = 3



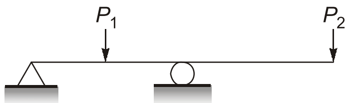
Number of unknown = 2

Number of equilibrium equation = 2



Number of unknown = 2

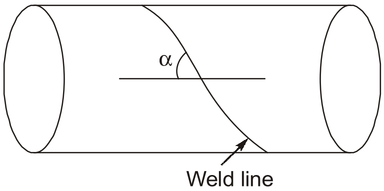
Number of equilibrium equation = 2



So, (a) is statically indeterminate structures.

End of Solution

Q.42 The figure shows a thin cylindrical pressure vessel constructed by welding plates together along a line that makes an angle $\alpha = 60°$ with the horizontal. The closed vessels has a wall thickness of 10 mm and diameter of 2 m. When the cylinder is subjected to an internal pressure of 200 kPa, the magnitude of the normal stress acting on the vessels is____ MPa. [Correct upto 1 decimal place]

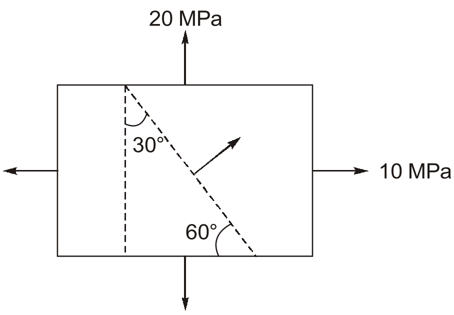


Ans. (12.5)

Given: P = 0.2 MPa, D = 2 m, t = 10 mm

$$\sigma_x = \sigma_L = \frac{PD}{4t} = \frac{0.2 \times 2000}{4 \times 10} = 10 \text{ MPa}$$

$$\sigma_y = \sigma_h = \frac{PD}{2t} = \frac{0.2 \times 2000}{2 \times 10} = 20 \text{ MPa}$$



$$\text{Normal stress, } (\sigma_n)_\theta = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$(\sigma_n)_{\theta=30^\circ} = \left(\frac{10+20}{2}\right) + \left(\frac{10-20}{2}\right)\cos(2\times 30^\circ) = 12.5 \text{ MPa}$$

End of Solution

Q.43 24000 kJ/min heat is supplied from 1200 K. Find maximum work if atmospheric temperature is 300 K (in kW).

Ans. (300)

$$Q_{in} = 24000 \text{ kJ/min} = 400 \text{ kW}$$

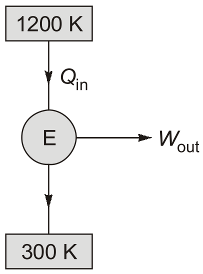
$$T_1 = 1200 \text{ K}, \quad T_2 = 300 \text{ K}$$

∴ Maximum work,

$$W_{max} = Q_{in} \times \eta_{carnot}$$

$$= 400\left(1 - \frac{300}{1200}\right)$$

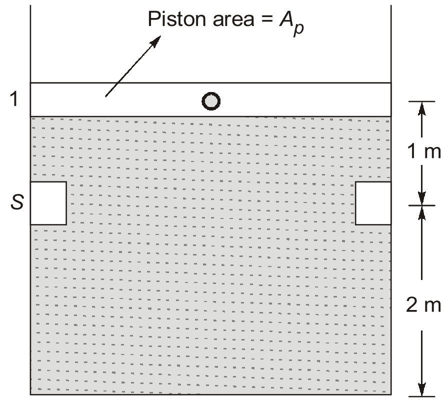
$$W_{max} = 300 \text{ kW}$$



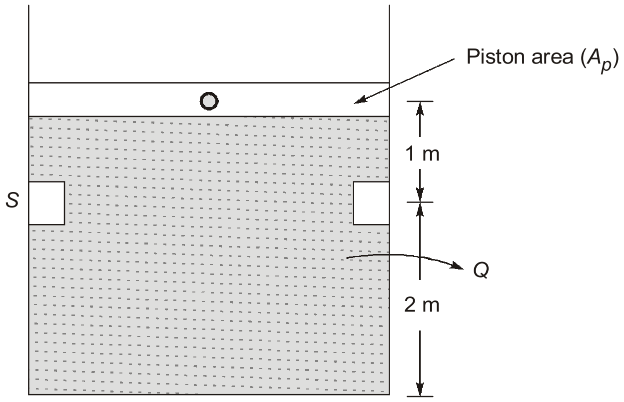
End of Solution

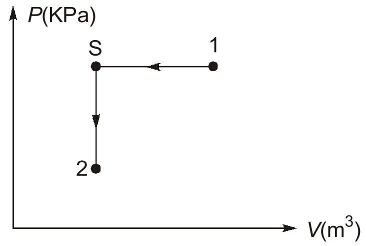
Q.44 Initial pressure 140 kPa, temperature 350°C, 1 m below it is a stopper.

The gas is cooled to 25°C, then what will be the specific work done during the process?



Ans. (–59.60)





$$P_1 = 140 \text{ KPa}$$
$$T_1 = 350°C = 350 + 273 = 623 \text{ K}$$
$$T_2 = 25°C = 25 + 273 = 298 \text{ K}$$
$$W_{1-s} = P_1V_1 - P_sV_s$$
$$= mR(T_1 - T_s)$$

For constant pressure process:

$$V \propto T$$

$$\Rightarrow \quad \frac{V_1}{V_s} = \frac{T_1}{T_s}$$

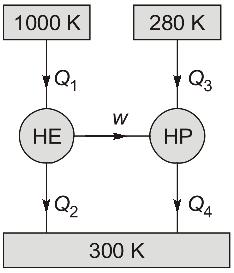
$$\Rightarrow \quad \frac{A_p \times 3}{A_p \times 2} = \frac{623}{T_s} \Rightarrow T_s = 415.33 \text{ K}$$

$$W_{1-s} = 1 \times 0.287 \times (623 - 415.33) = 59.60 \text{ kJ/kg}$$
$$W_{s-2} = 0 \quad [\because \text{ Constant volume process}]$$
$$\therefore \quad W_{1-2} = W_{1-s} + W_{s-2}$$
$$= 59.60 + 0 = 59.60 \text{ kJ/kg}$$

Since work is done on the gas, so work is negative.

End of Solution

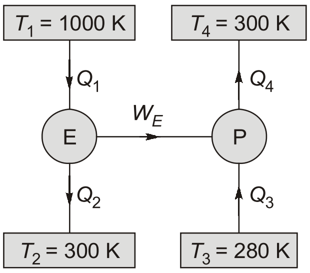
Q.45 The work output of a heat engine operating between temperatures 1000 K and 300 K is 150 kJ which is input to a heat pump operating between temperature 280 K and 300 K as shown in the figure below.



The net heat rejected to the reservoir at temperature 300 K is ________ kJ. [Answer in integer]

Ans. (1620)

$$T_1 = 1000 \text{ K}, \quad T_2 = 300 \text{ K} = T_4$$
$$Q_1 = 150 \text{ kJ}$$
$$T_3 = 280 \text{ K}$$



For heat engine,

$$\eta = 1 - \frac{300}{1000} = 1 - \frac{Q_2}{Q_1}$$

or $$Q_2 = 0.3Q_1 = 0.3 \times 150 = 45 \text{ kJ}$$

Now, $$Q_1 - Q_2 = 150 - 45$$

$\Rightarrow$ $$W_E = 105 \text{ kJ}$$

Now, $$COP_{HP} = \frac{Q_4}{W_E} = \frac{T_4}{T_4 - T_3}$$

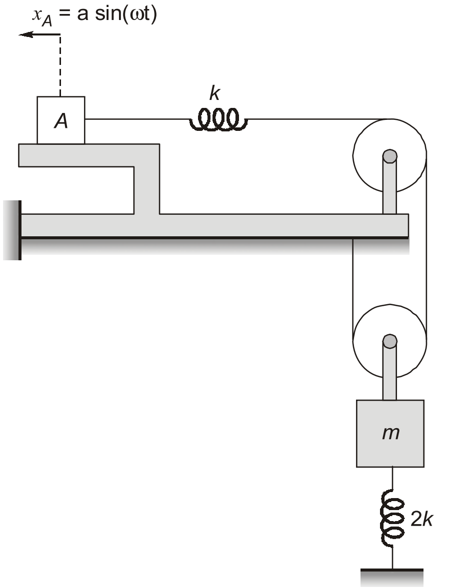
$\therefore$ $$\frac{Q_4}{105} = \frac{300}{300 - 280}$$

$\therefore$ $$Q_4 = 1575 \text{ kJ}$$

$\therefore$ $$Q_2 + Q_4 = 1575 + 45 = 1620 \text{ kJ}$$

End of Solution

Q.46 A vibratory systems consists of mass m, a vertical spring of stiffness 2k and a horizontal spring of stiffness k. The end A of the horizontal spring is given a horizontal motion x_A = a sinωt. The other end of the spring is connected to an inextensible rope that passes over two massless pulleys as shown. Assume m = 10 kg, k = 1.5 kN/m and neglect friction. The magnitude of critical driving frequency for which the oscillations of mass m tend to become excessively large is _____rad/s. [Answer in integer]



Ans. (30)

Given : m = 10 kg; k = 1.5 kN/m = 1500 N/m; ω_n = ?

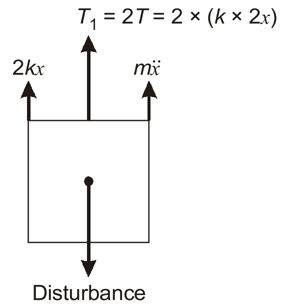
At time $t = t$;

Using D'Alembert's principle;

$$m\ddot{x} + 4kx + 2kx = 0$$

$$m\ddot{x} + 6kx = 0$$

$$\Rightarrow \quad \ddot{x} + \left(\frac{6k}{m}\right)x = 0; \quad \text{equation of motion}$$

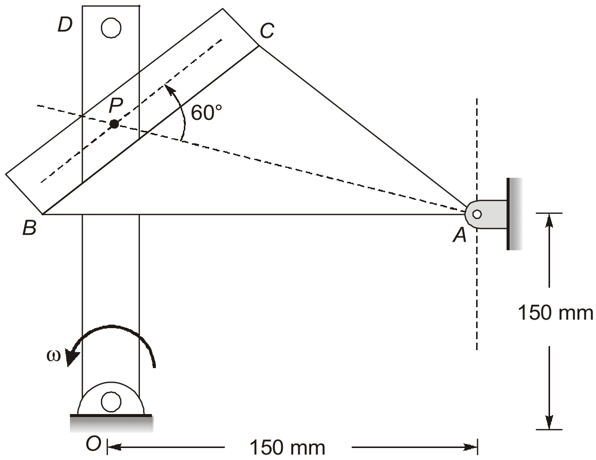


So, $$\omega_n = \sqrt{\frac{6k}{m}} = \sqrt{\frac{6 \times 1500}{10}}$$

$$= 30 \text{ rad/s}$$

End of Solution

Q.47 At the instant when OP is vertical and AP is horizontal, the link OD is rotating counter clockwise at a constant rate ω = 7 rad/s. Pin P on link OD slides in the slot BC of link ABC which is hinged at A and causes a clockwise rotation of the ABC. The magnitude of angular velocity of link ABC for this instant is_____ rad/s. [Correct upto 1 decimal place]



Ans. (0)

At the instant when AP is horizontal and OP is vertical, V_P will come in the line of AP, then perpendicular component of V_P will be zero.

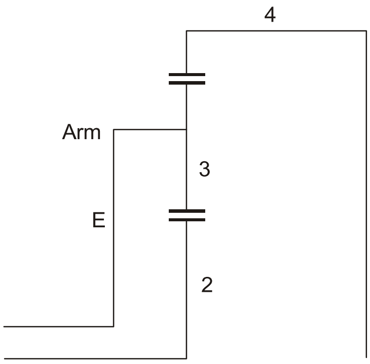
$\Rightarrow$ $V_P = (OP) \times \omega_{OP}$

$= (OP) \times 7$ m/s; direction is along AP

Hence, $\omega_{ABC} = 0$; No perpendicular component of velocity

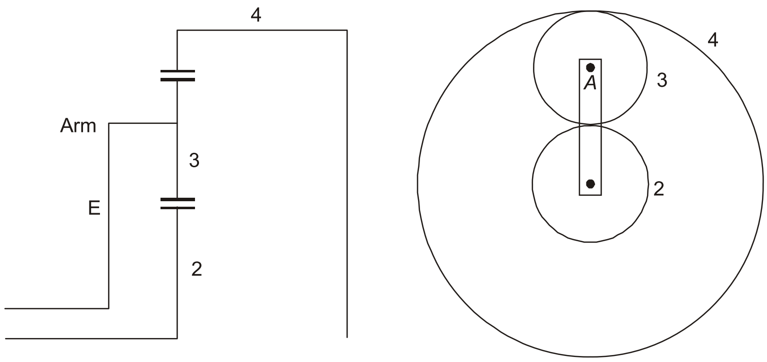
End of Solution

Q.48 The leval type-A train illustrated in the figure has gears with module m = 8 mm/teeth. Gear 2 and 3 have 19 and 24 teeth respectively. Gear 2 is fixed and internal gear 4 rotates at 20 rev/min counter clockwise. The magnitude of angular velocity of the arm is____ rev/min. [Correct upto 2 decimal places]



Ans. (15.58)

Gear train:



Given: $T_2 = 19$, $T_3 = 24$, $N_4 = 0$, $N_4 = 20$ rpm (CCW)

As $R_2 + 2R_3 = R_4$

$\Rightarrow$ $T_2 + 2T_3 = T_4$

$\Rightarrow$ $T_4 = 19 + 2 \times 24 = 67$

	A	Gear 2	Gear 3	Gear 4
Arm is fixed	0	$+x$	$-x \times \frac{T_2}{T_3} = -x \times \frac{19}{24}$	$-x \times \frac{T_2}{T_3} \times \frac{T_3}{T_4} = -x \times \frac{19}{27} \times \frac{27}{67}$ $= -x \times \frac{19}{67}$
Arm is free	$+y$	$+y + x$	$+y - x \times \frac{19}{24}$	$+y - x \times \frac{19}{67}$

$N_2 = y + x \Rightarrow x + y = 0$ ... (i)

and $N_4 = 20$ rpm $\Rightarrow$ $y - x \times \frac{19}{67} = 20$ ... (ii)

On solving equation (i) and (ii);

$x = -15.58$ rpm $= 15.58$ rpm (CW)

$y = 15.58$ (CCW)

End of Solution

Q.49 A linear spring-mass-dashpot-system with a mass of 2 kg is set in motion with viscous damping. If the nature frequency is 15 Hz, and the amplitude of two successive cycle measured are 7.75 mm and 7.20 mm, the coefficient of viscous damping in (Ns/m) is

(a) 7.51
(b) 4.41
(c) 2.52
(d) 6.11

Ans. (b)

$m = 2$ kg

$f_n = 15$ Hz

$\omega_n = 2\pi(f_n) = 2\pi \times 15 = 30\pi$ rad/s

$x_n = 7.75$ mm, $x_{n+1} = 7.20$ mm

Decrement ratio, $\frac{x_n}{x_{n+1}} = \frac{7.75}{7.20} = 1.07638$

Logarithmic decrement,

$$\delta = \log_e\left(\frac{x_n}{x_{n+1}}\right) = \log_e(1.07638)$$

$$\delta = 0.0736$$

$$\frac{2\pi\xi}{\sqrt{1-\xi^2}} = 0.0736$$

$$\Rightarrow \quad \xi = 0.0117$$

But, $$2\xi\omega_n = \frac{C}{m}$$

$$\Rightarrow \quad 2 \times 0.0117 \times 30\pi = \frac{C}{2}$$

$$\Rightarrow \quad C = 4.41 \text{ N/m/s}$$

End of Solution

Q.50 The change in kinetic energy of an engines is 300 J and minimum and maximum shaft speeds are ω_{min} = 220 rad/s and ω_{max} = 280 rad/s respectively. Assume that the torque time function is purely harmonic. To achieve a coefficient of fluctuation of 0.05, the moment of inertia (in kgm^2) of the flywheel to be mounted on the engine shaft is

(a) 0.113
(b) 0.096
(c) 0.053
(d) 0.071

Ans. (b)

Given: ΔE = 300 J, ω_{min} = 220 rad/s, ω_{max} = 280rad/s, C_s = 0.05, I = ?

Energy fluctuation, $\Delta E = I\omega^2 C_s$

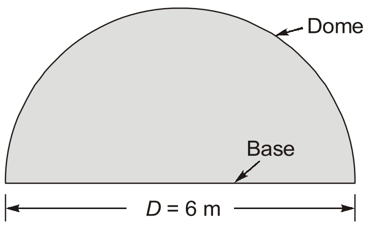
$$\Rightarrow \quad \Delta E = I \times \left(\frac{\omega_{max}+\omega_{min}}{2}\right)^2 \times C_s$$

$$\Rightarrow \quad 300 = I \times \left(\frac{280+220}{2}\right)^2 \times 0.05$$

$$\Rightarrow \quad I = 0.096 \text{ kgm}^2$$

End of Solution

Q.51 Consider a hemispherical furnace of diameter D = 6 m with a flat base the dome of the furnace has an emissivity of 0.7 and the flat base is a black body. The base and the dome are maintained at uniform temperature of 300 K and 1200 K, respectively. Under steady state condition, the rate of radiations heat transfer from the dome to base is _______ kW. Stefan Boltzman constant = 5.67 × 10^{-8} W (m^{2}k^4)

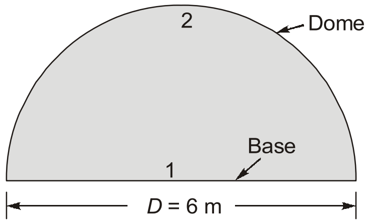


Ans. (2726.97)

Given: $T_1 = 300$ K, $T_2 = 1200$ K, $D = 6$ m, $F_{11} = 0$, $F_{12} = 1$, $\epsilon_1 = 1$, $\epsilon_2 = 0.7$

$$A_1 = \pi R^3 = \pi(3)^2 = 9\pi \text{ m}^2$$

$$A_2 = 2\pi R^2 = 2\pi(3)^2 = 18\pi \text{ m}^2$$



Heat transfer,

$$q = \frac{\sigma\left(T_2^4 - T_1^4\right)}{\frac{1-\epsilon_1}{\epsilon_1 A_1} + \frac{1}{A_1 F_{12}} + \frac{1-\epsilon_2}{\epsilon_2 A_2}}$$

$$= \frac{\left(5.67 \times 10^{-8}\right) \times \left(1200^4 - 300^4\right)}{\frac{1}{9\pi \times 1} + \frac{1-0.7}{0.7 \times 18\pi}}$$

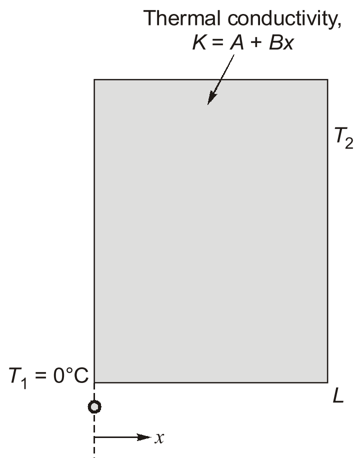
$$= 2726966.198 \text{ W} \qquad \left[\because \frac{1-\epsilon_1}{\epsilon_1 A_1} = 0\right]$$

$$= 2726.966198 \text{ kW}$$

$$\simeq 2726.97 \text{ kW}$$

End of Solution

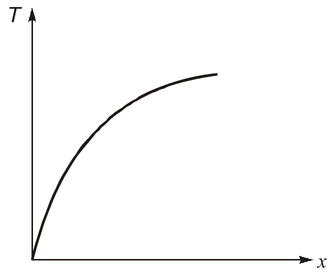
Q.52 For a rectangular slab without internal heat generation, the thermal conductivity changes with x as $K = A + Bx$



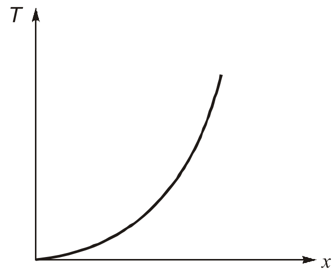
where A and B are positive real number

Which one of the following variation of temperature with x is correct?

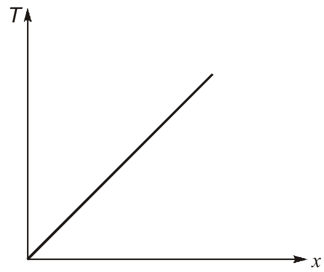
(a)



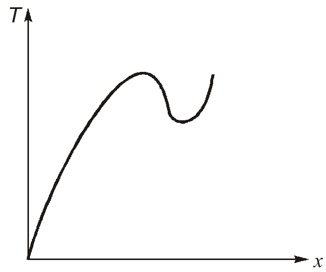
(b)



(c)



(d)



Ans. **(a)**

$$k = A + Bx$$

where A and B are positive real number

So with increase with x, k increases

Energy equation;

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \cancel{\dot{q}}^{\,0} = 0$$

$$\frac{\partial}{\partial x}\left((A+Bx)\cdot\frac{\partial T}{\partial x}\right) = 0$$

On integration,

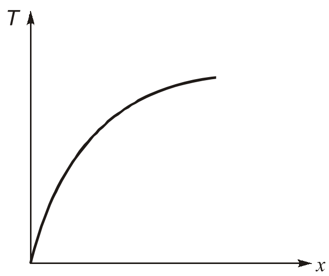
$$(A+Bx)\cdot\frac{\partial T}{\partial x} = C_1$$

$$\frac{\partial T}{\partial x} = \frac{C_1}{A+Bx}$$

On integration,

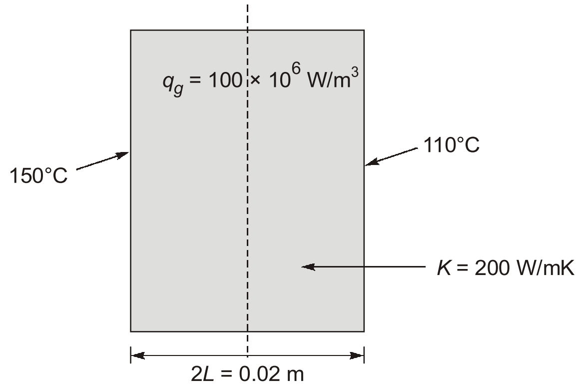
$$T = \text{logarithmic function of } x$$

Hence, variation of T with x is given as;



End of Solution

Q.53 A rectangular slab with uniform rate of internal heat generation of 100×10^6 W/m^3 is shown in the figure below.



The temperature of the left and right faces are maintained constant at 150°C and 110°C respectively. The thermal conductivity of the slab is 200 W/K, the location of maximum temperature from left face of the slab is ______ mm.

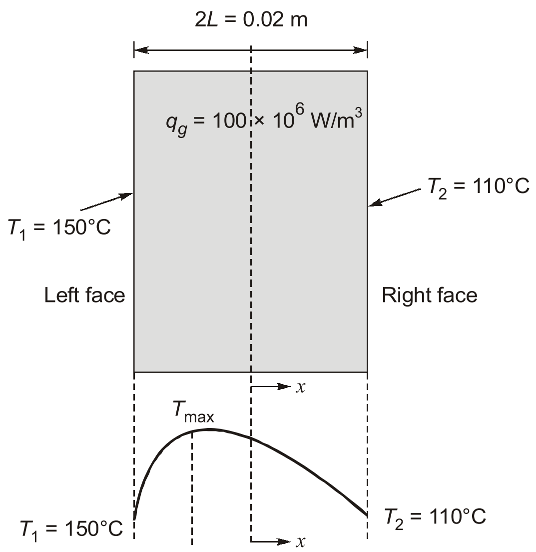
Ans. (6)

For uniform internal heat generation and constant thermal conductivity in a rectangular slab,

$$\frac{\partial^2 T}{\partial x^2} + \frac{q_g}{k} = 0$$

$$\Rightarrow \quad T = -\frac{q_g x^2}{2k} + C_1 x + C_2$$

Temperature variation is parabolic inside the slab



At $x = -L,\ T = T_1 = 150°C$

$$\Rightarrow \quad 150 = -\frac{q_g x^2}{2k} - C_1 L + C_2 \quad \text{... (i)}$$

and at $x = L,\ T = T_2 = 110°C$

$$110 = -\frac{q_g L^2}{2k} + C_1 L + C_2 \quad \text{... (ii)}$$

Using equation (i) and (ii)

$$C_1 = \frac{T_2 - T_1}{2L} = \frac{110 - 150}{2\times(0.01)} = -2000$$

At T_{max}; $\frac{dT}{dx} = 0$

$$\Rightarrow \quad \frac{dT}{dx} = -\frac{q_g x}{k} + C_1$$

$$\Rightarrow \quad 0 = -\frac{(100\times10^6)x}{200} - 2000$$

$$\Rightarrow \quad x = -4 \times 10^{-3}\ \text{m} = -4\ \text{mm}$$

Distance of T_{max} left face $= L - |x| = 10 - 4 = 6$ mm

End of Solution

Q.54 Consider incompressible laminar flow over a flat with free stream velocity of U_∞. The nusselt number corresponding to this flow velocity is Nu_1. If the free stream velocity is double the Nusselt number changes to Nu_2. Choose the correct option for Nu_2/Nu_1 is

(a) $\sqrt{2}$

(b) $\frac{1}{\sqrt{2}}$

(c) 1.26

(d) 1

Ans. **(a)**

For laminar flow over flat plate,

$Nu \propto Re^{0.5}\ Pr^{1/3}$, where Re is Reynolds number and Pr is the Prandtl number.

$$\because \quad Re = \frac{U_\infty x}{\nu}$$

$$\therefore \quad Nu \propto U_\infty^{0.5}$$

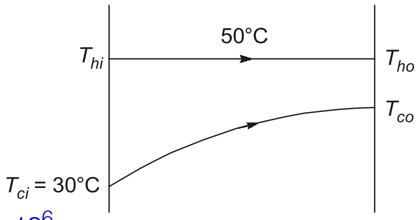
or,

$$\frac{Nu_2}{Nu_1} = \sqrt{\frac{U_{\infty,2}}{U_{\infty,1}}} = \sqrt{2}$$

End of Solution

Q.55 In a shell and tube heat exchanger (single shell and 20000 tubes), steam condenses in the shell at 50°C at a rate of 430 kg/s. Water flow through the tube at the rate of 1 kg/s and enters the tube at 30°C. The latent heat of condensation is 2.326 MJ/kg. The effectiveness of heat exchanger is ______.

Ans. **(0.625)**



Given: $\dot{m}_h = 430$ kg/s , LH = 2.326 MJ/kg

Effectiveness, $$\epsilon = \frac{\dot{q}}{q_{max}}$$

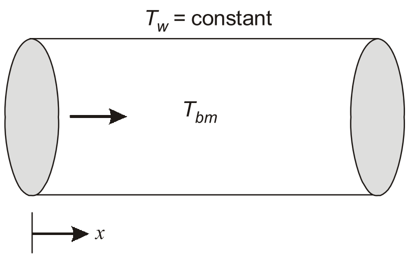
Now, $$q = \dot{m}_h \times LH = 430 \times 2.326 \times 10^6$$
$$= 1000.18 \text{ MW}$$

and $$q_{max} = \text{Cmin}\,(T_{hi} - T_{ci})$$
$$= 20000 \times 1 \times 4000\,(50 - 30)$$
$$= 1600 \text{ MW}$$

∴ $$\epsilon = \frac{1000.18}{1600} = 0.625$$

End of Solution

Q.56 For constant wall surface temperature of pipe flow of fluid



(a) $\frac{dT_m}{dx} = 0$

(b) Nu_x = f(x) linear variation

(c) $\frac{\partial T}{\partial x} = 0$ (fully developed)

(d) If $T_w > T_{bm}$, temperature changes exponentially

Ans. **(b)**

In fully developed zone, Nusselt number is given by,

$$Nu_x = \frac{h_x \times x}{k}$$

Since, heat transfer coefficient is constant in fully developed flow, and thermal conductivity is constant. Hence, Nusselt number varies linearly with 'x'. So option (b) is correct.

End of Solution