PW GATE WALLAH

ENGINEERING SCIENCE (XE)

EXAM HELD ON

10th FEBRUARY 2024

EVENING SESSION

DETAILED SOLUTION BY TEAM

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XE- GA | General Aptitude

[MCQ-2]

Q.1. In the 4 × 4 array shown below, each cell of the first three rows has cross or a number.

1	×	4	3
×	5	5	4
3	×	6	×

The number in a cell represents the count of the immediate neighbouring cells [left, right, top, bottom, diagonal] not having a cross (x). Given that the last row has no cross. The sum of four number to be filled in the last row is

(a) 12 (b) 9
(c) 11 (d) 10

Sol. **(c)**

1	×	4	3
×	5	5	4
3	×	6	×
2	4	3	2

Sum of fourth row = 2 + 4 + 3 + 2 = 11

[MCQ-1]

Q.2. In an engineering collage of 10000 students, 1500 like neither their core branches nor other branches. The number of students who like core branches is $1/4^{th}$ of the number of students who like other branches. The number of students who like both their core and other branch is 500.

The number of students who like their core branch is

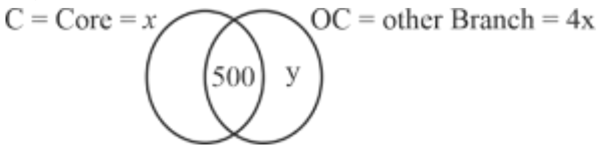
(a) 1500 (b) 1800
(c) 1600 (d) 3500

Sol. **(b)**

Number of students = 10000

Number of students not interested in both = 1500

∴ When diagram represent 10000 – 1500 = 8500



x = core, y = other branch (not core) = 4x

x + 4x = 8500 + 500

5x = 9000

x = 1800

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[MCQ-1]

Q.3. Two Wizards try to create a spell using all the four elements, water, air, fire and earth. For this, they decide to mix all these elements in all possible orders. They also decide to work independently after trying all possible combination of element, they conclude that the spell does not work. How many attempts does each wizard make before coming to this conclusion, independently?

(a) 24 (b) 16

(c) 48 (d) 12

Sol. **(a)**

We use combination of $4 \times 3 \times 2 \times 1 = 24$

[MCQ-1]

Q.4. Sequence 6, 9, 14, x, 30, 41, possible value of x.

(a) 18 (b) 25

(c) 21 (d) 20

Sol. **(c)**

6 9 14 x 30 41

+3 +5 +7 +9 +11

$x = 14 + 7 = 21$

[MCQ-2]

Q.5. A person sold two different items at the same price. He made 10% profit in one item and 10% loss in the other item. In selling price these two items, the person made a total of

(a) 1% Profit (b) 2% Loss

(c) 2% Profit (d) 1% Loss

Sol. **(d)**

$SP_1 = SP_2$

10% profit × 10% loss

$1.1 \times 0.9 = 0.99$

Less then 1 by 0.01

$\therefore$ 1% loss.

OR

When the selling price of the both item is equal and the profit and loss is same we get loss.

$$\text{Loss\%} = \frac{x^2}{100} = \frac{10^2}{100} = 1\%.$$

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[MCQ-2]

Q.6. A cube is to be cut into 8 pieces of equal size and shape. There each cut should be straight and it should not stop till it reaches the other end of cube. The minimum number of such cut required is

(a) 8 (b) 4

(c) 7 (d) 3

Sol. **(d)**

As x cut on each edge gives number of small cubes = $(x + 1)^3 = 8$ (given)

$\therefore$ x = 1 cut on each edge

Thus, three cuts take place.

[MCQ-1]

Q.7. If '→' denotes increasing order of intensity. Then the meaning of words [walk → jog → sprint] is analogues to [bothered → _______ → daunted].

Which of the given option is appropriate to fill the blank.

(a) Fazed (b) Fused

(c) Phased (d) Phrased

Sol. **(a)**

To make somebody worried or nervous.

[MCQ-1]

Q.8. For positive non-zero real variables x and y if $\ln\left(\frac{x+y}{2}\right)=\frac{1}{2}[\ln(x)+\ln(y)]$ then the value of $\frac{x}{y}+\frac{y}{x}$ is

(a) 1 (b) 4

(c) 1/2 (d) 2

Sol. **(d)**

Given, $\ln\left(\frac{x+y}{2}\right)=\frac{1}{2}\{\ln x+\ln y\}$

$\Rightarrow \quad 2\ln\left(\frac{x+y}{2}\right)=\ln(xy)$

$\Rightarrow \quad \left(\frac{x+y}{2}\right)^2=xy$

$\Rightarrow \quad x^2+y^2+2xy=4xy$

$\Rightarrow \quad x^2+y^2=2xy$

$\Rightarrow \quad \frac{x^2+y^2}{xy}=2$

$\Rightarrow \quad \frac{x}{y}+\frac{y}{x}=2$

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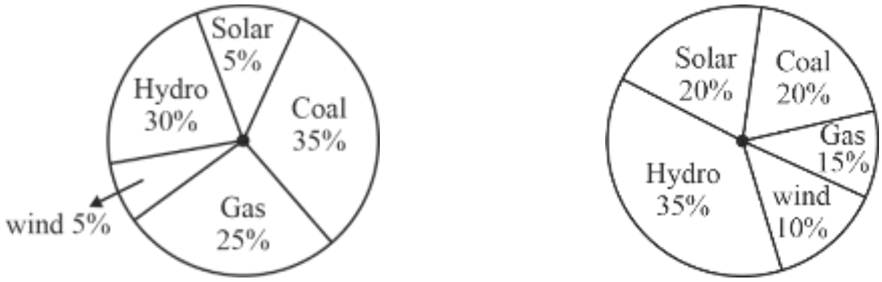
[MCQ-2]

Q.9. The Pie chart depict the shares of various power generation technologies in the total electricity generation of a country for the year 2007 and 2023.



The renewable sources of electricity generation consist of hydro solar and wind. Assuming that the total electricity generated remains the same from 2007 to 2023. What is the % increase in the share of the renewable sources of electricity generation over this period?

(a) 62.5% (b) 50%

(c) 25% (d) 77.5%

Sol. **(a)**

For 2007

Renewable energy generate electricity

Hydro + Solar + Wind = 30% + 5% + 5% = 40%

For 2023

= 35% + 20% + 10% = 65%

$$\% \text{ increase in share } = \left(\frac{65-40}{40}\right)\% = 62.5\%$$

[MCQ-2]

Q.10. Sequence of the following sentences in a coherent passage.

P: This fortuitous geological event generated a colossal amount of energy and heat that resulted in the rocks rising to an average height of 4 km across the contact zone.

Q: Thus the geophysicists tend to think of the Himalayas as an active geological event rather than as a static geological feature.

R: The natural process of the cooling of this massive edifice absorb a large quantity of atmospheric carbon dioxide, altering the earth's atmosphere and making it better suited for life.

S: Many Millennia age a breakaway chink of bedrock from the Antarctic plate collied with the massive Eurasian plate.

(a) SRPQ (b) SPRQ

(c) QPSR (d) QSPR

Sol. **(b)**

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XE- A | Engineering Mathematics

[MCQ-1]

Q.1. For integer K, the differential equation $x^2\frac{d^2y}{dx^2}-3x\frac{dy}{dx}+(K+2)y=0$ is transfer and into $(D-2)^2y = 0$, where $D=\frac{d}{dt}$ and $t = \log_e x$. K value is _______.

Sol. **(2)**

Given equation is $x^2\frac{d^2y}{dx^2}-3x\frac{dy}{dx}+(K+2)y=0$

$\Rightarrow$ $\{D(D-1)-3D+(k+2)\}\ y=0$

$\Rightarrow$ $\{D^2-4D+(k+2)\}y=0$

$\Rightarrow$ $k+2=4$

$\Rightarrow$ $k=2$

[MCQ-1]

Q.2. $f(x)=\begin{cases}\pi+x, & -\pi\le x<0\\ 0, & 0\le x<\pi\end{cases}$

With $f(x + 2\pi) = f(x)$. If f(x) represents the Fourier series of f(x), then the value of $f\left(-\frac{\pi}{2}\right)+f(0)$ is _______.

(a) $\frac{3\pi}{2}$ (b) 0

(c) $\frac{\pi}{2}$ (d) π

Sol. **(c)**

Given, $f(x)=\begin{cases}\pi+x, & -\pi\le x<0\\ 0, & 0\le x<\pi\end{cases}$

If F(x) is the Fourier series expansion of f(x), then

$f(x) = F(x)$

$\therefore\quad F\left(-\frac{\pi}{2}\right)=f\left(-\frac{\pi}{2}\right)=\pi+\left(-\frac{\pi}{2}\right)=\frac{\pi}{2}$

$F(0) = f(0) = 0$

$\therefore\quad F\left(-\frac{\pi}{2}\right)-F(0)=\frac{\pi}{2}-0=\frac{\pi}{2}$

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[MCQ-1]

Q.3. Let y be a non-zero quadratic polynomial satisfying the differential equation $(2+x^2)\frac{d^2y}{dx^2}+x\frac{dy}{dx}-ky=0$.

K is a real constant. If y(1) = 1, then the value of the integral $\int_0^1 2y\,dx$ is

(a) 4/3 (b) 2/3

(c) 1/3 (d) 1

Sol. **(a)**

Given, $y = ax^2 + bx + c$, $y(1) = 1$

$$(2+x^2)\frac{d^2y}{dx^2}+x\frac{dy}{dx}-ky=0$$

$$\int_0^1 2y\,dx = ?$$

$y = ax^2 + bx + c$

$\Rightarrow$ $y' = 2ax + b,\ y'' = 2a$

$\Rightarrow$ $(2 + x^2)\,2a + x(2ax + b) - k(ax^2 + bx + c) = 0$

$\Rightarrow$ $4a + 4ax^2 + bx - kax^2 - kbx - kc = 0$

$\Rightarrow$ $(4a - ka)x^2 + (b - kb)x + (4a - kc) = 0$

$\because$ $4a - ka = 0$

$\because$ $a \neq 0$

$\Rightarrow$ $k = 4$

Also $b - kb = 0$

$\Rightarrow$ $-3b = 0$

$b = 0$

$4a - kc = 0$

$4a - 4c = 0$

$\Rightarrow$ $a = c$

$\therefore$ $y = ax^2 + a$

$y = 1, x = 1$

$1 = a \times 1 + a$

$\Rightarrow$ $a = \frac{1}{2}$

$\therefore$ $y = \frac{1}{2}(x^2+1)$

$$\int_0^1 2y\,dx = \int_0^1 2\times\frac{1}{2}(x^2+1)\,dx = \left[\frac{x^3}{3}+x\right]_0^1$$

$$\int_0^1 2y\,dx = \frac{4}{3}$$

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[MCQ-1]

Q.4. Consider $F(z) = e^z$, where $z = x + iy$ and $i = \sqrt{-1}$ which of the following is correct.

(a) $|F| = 1$

(b) F is not periodic

(c) F is periodic

(d) arg (F) = $y \pm n\pi$ for all $n = 0, 1, 2, ..$

Sol. **(c)**

$F(z) = e^{z + 2\pi i} = e^{z+(2k\pi i)}$

$k = 1, 2, 3, \ldots$

$\therefore$ F(z) Periodic with period $2\pi i$.

[MCQ-1]

Q.5. $\int_0^{1/2} e^{-x^2} dx$, Trapezoidal rule with step size $h = \frac{1}{8}$ is _______.

Sol. **(0.46)**

$$I = \int_0^{1/2} e^{-x^2} dx$$

Step size $h = \frac{1}{8}$

$\therefore$

0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
1	$e^{-1/64}$	$e^{-1/16}$	$e^{-9/64}$	$e^{-1/4}$

$$\therefore \quad I = \frac{\left(\frac{1}{8}\right)}{2}\left[1 + e^{-1/4} + 2\{e^{-1/64} + e^{-1/16} + e^{-9/64}\}\right]$$

$$\Rightarrow \quad I = \frac{1}{16}\left[1 + e^{-1/4} + 2\{e^{-1/64} + e^{-4/64} + e^{-9/64}\}\right]$$

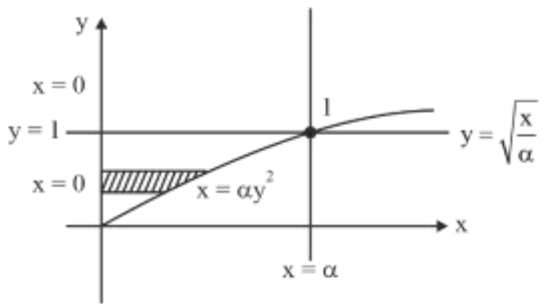
$$\Rightarrow \quad I = 0.46$$

$$\int_0^{1/2} e^{-x^2} dx = 0.46$$

[MCQ-2]

Q.6. $\int_0^{\alpha} \int_{\sqrt{x/a}}^{1} e^{y^3} dy\, dx = e - 1, \alpha > 0$, the value of α _______.

Sol. **(3)**



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Given limits are

$$y=\sqrt{\frac{x}{\alpha}} \Rightarrow y^2=\frac{x}{\alpha}$$

$\Rightarrow \quad x=\alpha y^2$

$y=1$

$x=0,\ x=\alpha$

On changing order of integration

$$=\int_{y=0}^{y=1}\int_{x=0}^{x=\alpha y^2} e^{y^3}\cdot dx\cdot dy$$

$$\Rightarrow \quad =\int_{y=0}^{y=1} e^{y^3}(\alpha y^2-0)dy=\int_{y=0}^{y=1} e^{y^3}(\alpha y^2)dy$$

$$=\frac{\alpha}{3}\times\int_0^1 e^{y^3}(3y^2)dy=\frac{\alpha}{3}\times\int_0^1 d\left(e^{y^3}\right)$$

$$=\frac{\alpha}{3}e^{y^3}\Big|_0^1=\frac{\alpha}{3}\times(e-1)$$

$$\therefore \quad \frac{\alpha}{3}=1\Rightarrow \alpha=3$$

$\Rightarrow \quad \alpha=3$

[MCQ-1]

Q.7. Let A be a 3 × 3 matrix whose eigen values are 2, 3, 4 and let I be the identity matrix of order 3.

If $A^{-1}=\frac{1}{2k}(A^2-9A)+\frac{13I}{k}$, for some integer $k\neq 0$, value of k ________.

Sol. **(12)**

$\Rightarrow \quad 2k\,A^{-1}=A^2-9A+26\,I$

$\Rightarrow \quad 2k\,I=A^3-9A^2+26A$

They should have eigen value

$\therefore \quad 2k(1)=(2)^3-9(2)^2+26(2)\Rightarrow 2k=24$

$\Rightarrow \quad k=12$

OR

$27-9(3)^2+26(3)=2k$

$\Rightarrow \quad 27-81+78=2k$

$\Rightarrow \quad k=12$

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[MSQ-2]

Q.8. Let P and Q be two square matrices of the same order. Then which of the following matrices is/are necessarily equal to $(P + 2Q)^2$

(a) $P^2 + 2PQ + 2QP + 4Q^2$ (b) $P(P + 2Q) + Q[2P + 4Q]$

(c) $(P + 2Q)(2Q + P)$ (d) $P^2 + 4PQ + 4Q^2$

Sol. **(a, b and c)**

(a) $(P + 2Q)^2 = P^2 + 2QP + 2PQ + 4Q^2$

Since QP may or may not equal to PQ

$\therefore$ $(P + 2Q)^2 \neq P^2 + 4PQ + 4Q^2$

(b) $(P + 2Q)^2 = (P + 2Q)(P + 2Q)$

$= P(P + 2Q) + 2Q(P + 2Q)$

$= P(P + 2Q) + Q(2P + 4Q)$

(c) $(P + 2Q)^2 = (P + 2Q)(2Q + P)$

[MCQ-2]

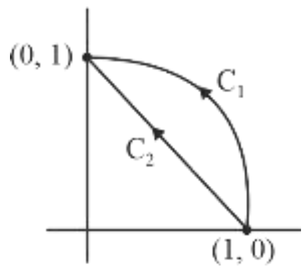
Q.9. Consider the vector field.

$\vec{F} = (2x + y^2)\hat{i} + (2xy + 3y)\hat{j}$ and $\alpha_m = \int_{C_m} \vec{F}\cdot d\vec{r} : m = 1, 2$ where C_1 is an arc of the unit circle connecting the point (1, 0) and (0, 1) and C_2 is the straight line connecting the point (1, 0) and (0, 1) then the value (in integer) of $2(\alpha_1^2 + 3\alpha_2^2)$ is _______.

Sol. **(2)**

Given, $\vec{F} = (2x + y^2)\hat{i} + (2xy + 3y)\hat{j}$

$\alpha_m = \int_{C_m} \vec{F}\cdot d\vec{r} : m = 1, 2$



For vector $\vec{F}$ to be irrotational

$\Rightarrow$ $\frac{\partial}{\partial x}(2 \times y \times 3y) = \frac{\partial}{\partial y}(2x + y^2)$

$\Rightarrow$ $2y = 2y$

Hence $\vec{F}$ is irrotational

$\Rightarrow$ $\alpha_1 = \alpha_2$

$C_2 : \frac{x}{1} + \frac{y}{1} = 1$

$y = 1 - x, dy = -dx$

$\alpha_1 = \int_{x=1}^{x=0} (2x + (1-x)^2)dx + (2x + (1-x) + 3(1-x))(-dx)$

On solving

$\alpha_1 = \frac{1}{2}$

$\therefore$ $2(\alpha_1^2 + 3\alpha_2^2) = 2\left(\frac{1}{4} + 3\times\frac{1}{4}\right) = 2$

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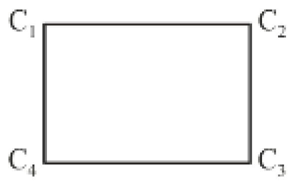
[MCQ-2]

Q.10. There are four cities, namely C_1, C_2, C_3 and C_4. The cities are directly connected by four roads as shown in the picture given below, that is C_1 is connected with C_2, C_2 is connected with C_3, C_3 is connected with C_4 and C_4 is connected with C_1. The probability of any road. Getting independently blocked is 1/3. Let E_1 be the event of travelling from C_1 to C_3 via C_2 and E_2 be the event of travelling from C_1 to C_3 via C_4. Then, which of the following statements is correct?



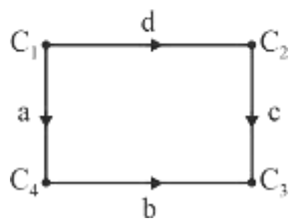
(a) $P(E_1 \cup E_2) = \frac{56}{81}$

(b) $P(E_1 \cap E_2) = 0$

(c) $P(E_1 \cup E_2) = 8/9$

(d) $P(E_1/E_2) \neq P(E_1) = \frac{4}{9}$

Sol. **(a)**



$E_1 \rightarrow$ Event of going from C_1 to C_3 via C_2.

$E_2 \rightarrow$ Event of going from C_1 to C_3 via C_4

$P(E_1 \cup E_2) = 1 - P(E_1^C \cap E_2^C)$

= 1 – P (Not going from C_1 to C_3)

Let B → Block ; F → Free ;

Possibilities of Not going are

a	b	c	d
B	F	B	F
B	F	F	B
F	B	B	F
F	B	B	F
B	F	B	B
F	B	B	B
B	B	B	F
B	B	F	B
B	B	B	B

Given P(Block) = $\frac{1}{3}$

∴ Probability of $E_1 \cup E_2$.

$$= 1 - \left\{\left(\frac{1}{3} \times \frac{2}{3}\right)^2 \times 4 + \left(\frac{1}{3}\right)^3 \times \frac{2}{3} \times 4 + \left(\frac{1}{3}\right)^4\right\}$$

$$= 1 - \left\{\frac{16+8+1}{81}\right\} = \frac{56}{81}$$

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[MCQ-1]

Q.11. Assume that f[0, 1] R is continuous on [0, 1] and differentiable on [0, 1] such that f(x + h) = f + hf′(x + θh) for assume 0 < θ < 1 if $f(x) = x^2(1+x)$ and θ is expressed in terms of x and h, then the value of $\lim_{h\to\theta} \theta(x,h)$ is

(a) $\frac{1}{3}$ (b) $\frac{4}{5}$

(c) $\frac{1}{2}$ (d) $\frac{1}{4}$

Sol. **(c)**

Given

$f(x) = x^2(1 + x)$

By Lagrange's mean value theorem

$f(a + h) = f(a) + hf'(a + \theta h)$

Given interval is (0, 1)

a = 0

$\therefore f(h) = f(o) + hf^1(\theta h)$

$h^2 \times (1+h) = 0 + h \times \{\theta h(2 + 3\theta h)\}$

$h^2 \times (1+h) = \theta h^2 \times (2 + 3\theta h)$

$(1+h) \times 2\theta + 3\theta^2 h$

At h → 0;

$1 = 2\theta$

$\theta = 1/2$

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Engineering Science (XE)

XE- B | Fluid Mechanics

[MCQ-1]

Q.1. For an immersed neutrally buoyant body to be in stable equilibrium, the center of gravity of the body is directly.

(a) above the center of buoyancy (b) below the center of buoyancy

(c) above the metacenter (d) above the metacenter

Sol. (b)

For stable equilibrium, centre of gravity is below the centre of buoyancy.

[MCQ-1]

Q.2. Let $\vec{r}, \vec{V}$, and m be positioning vector, velocity vector, and mass, respectively in a control mass system. Which of the following properties is considered as conserved extensive property in Reynold's transport theorem to obtain the angular momentum equation?

(a) $\vec{r} \times m\vec{V}$ (b) m

(c) $m\vec{V}$ (d) $\vec{r} \times \vec{V}$

Sol. (a)

By Reynold's transport theorem,

$$\left.\frac{DB}{Dt}\right|_{sys} = \frac{\partial}{\partial t}\left(\int_{V} \beta(\rho d V)\right) + \int_{s} \beta(\rho \vec{V} \cdot \hat{n}) ds$$

For angular momentum equation,

$$B = \vec{r} \times m\vec{V}$$

[MCQ-1]

Q.3. Consider the velocities u, v, and w in x-, y-, and z- direction respectively. The vorticity expression in y–z plane is

(a) $\frac{\partial v}{\partial y} - \frac{\partial w}{\partial z}$ (b) $\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}$

(c) $\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}$ (d) $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$

Sol. (b)

y – z plane

$\Omega_x = 2\,\omega_x$

$$\Omega_x = \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right)$$

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[MCQ-1]

Q.4. For incompressible, laminar fully-developed flow through a circular pipe, Darcy friction factor and Fanning factor are represented as f and C_f, respectively. Which one at the following options is correct?

(a) $f = 4C_f$ (b) $f = 0.25\ C_f$

(c) $f = 0.025\ C_f$ (d) $f = 0.5\ C_f$

Sol. **(a)**

Laminar fully-developed flow

$f \rightarrow$ Darcy's friction factor

$C_f \rightarrow$ Fanning factor

$f = 4\ C_f$

[MCQ-1]

Q.5. For the laminar, incompressible flow over a flat plat with uniform free stream velocity, the axial pressure gradient within the boundary layer is

(a) equal to zero (b) less than zero

(c) equal to the axial velocity gradient (d) greater than zero

Sol. **(a)**

For the laminar, incompressible flow over a flat plat with uniform free stream velocity,

$$\frac{\partial p}{\partial x} = 0\,,\ \left(\text{Since}\,\frac{dU_\infty}{dx} = 0\right)$$

[MCQ-1]

Q.6. The locus of temporary locations of all particles that have passed through a fixed point in the flow field at a particular instant is known as

(a) timeline (b) streakline

(c) streamline (d) pathline

Sol. **(b)**

[MCQ-1]

Q.7. The hydraulic diameter for a circular pipe of radius R is

(a) R (b) 2R

(c) 4R (d) 0.5 R

Sol. **(b)**

hydraulic diameter $(D_h) = \dfrac{4\times A_c}{\text{Wetted Perimeter}}$

$$= \frac{4\times\pi\times R^2}{2\pi R} = 2R$$

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[NAT-1]

Q.8. The absolute pressure in a chamber is measured as 400 mm of mercury at a location where the atmospheric pressure is 700 mm of mercury. a vacuum gauge connected to the chamber reads _____ mm of mercury (Answer in integer)

Sol. **(300)**

$$(P_A)_{abs} = 400\,\text{mm of Hg}$$

$$P_{atm} = 700\,\text{mm of Hg}$$

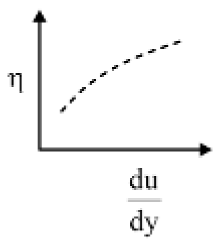
$$(P_A)_{gauge} = 400 - 700$$

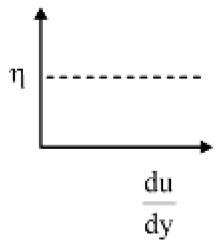
$= -300$ mm of Hg

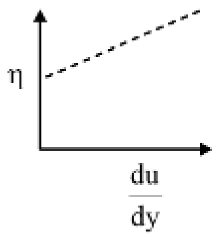
$= 300$ mm of Hg vacuum

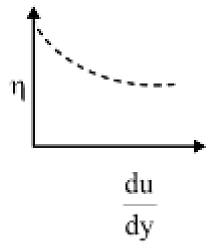
[MCQ-1]

Q.9. Which one of the following figures shows the CORRECT dependence of apparent viscosity (η) on rate of shear strain (du/dy) for Pseudoplastic fluids.

(a)


(b)


(c)


(d)


Sol. **(d)**

$$\eta = k\left(\frac{du}{dy}\right)^{n-1}$$; k is flow consistency index.

For pseudoplastic; $n < 1$

$$\therefore \text{As} \left(\frac{du}{dy}\right)\uparrow ; \eta \downarrow$$

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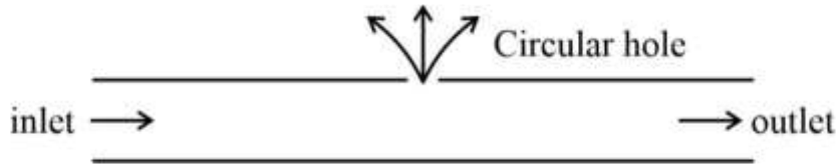
Engineering Science (XE)

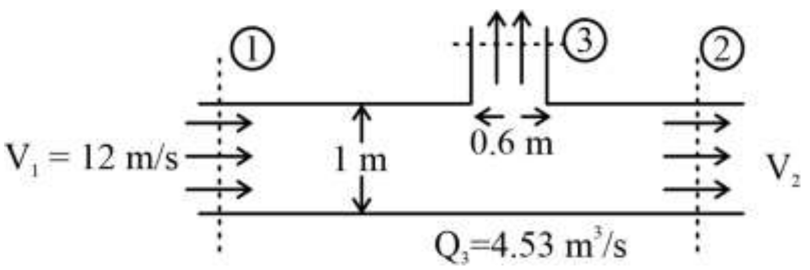
[NAT-2]

Q.10. Consider the steady, incompressible flow of water in a horizontal pipe of constant diameter 1m with an inlet velocity of 12 m/s.



As shown, in figure, water is lost through a circular hole of diameter 0.6 m at the rate of 4.53 m^3/s. the outlet velocity (in m/s, rounded off to two decimal places)

Sol. **(6.23)**



From continuity equation

$Q_1 = Q_2 + Q_3$

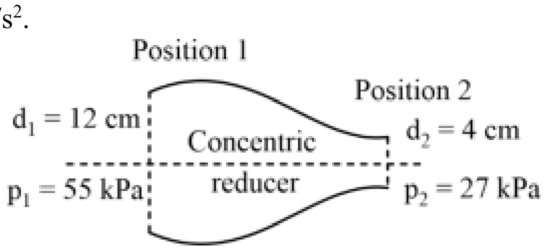
$A_1V_1 = A_2V_2 + 4.53$

$$\frac{\pi}{4}\times 1^2 \times 12 = \frac{\pi}{4}\times 1^2 \times V_2 + 4.53$$

$$V_2 = 6.23 m/s$$

[NAT-2]

Q.11. Consider the incompressible, steady and irrotational flow through a concentric reducer in a horizontal pipeline. The pipeline reduces from d_1 = 12 cm to d_2 = 4 cm as shown in figure. The pressure at position 1 and Position 2 of the reducer is p_1 = 55 kPa and p_2 = 27 kPa, respectively. The specific weight of fluid is 7 kN/m^3. Acceleration due to gravity is 10 m/s^2.



Neglecting frictional effects, the mass flow rate (in kg/s, round off to two decimal place) of the fluid through the reducer is ______.

Sol.11. **(7.91)**

$$\dot{m} = \rho A_1 V_1 = \rho A_2 V_2$$

Bernoulli's equation between 1 and 2

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$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2$$

$$\frac{V_1^2-V_2^2}{2g}=\frac{P_2-P_1}{\rho g} \quad ...(i)$$

From continuity equation

$A_1V_1 = A_2V_2$

$12^2 \times V_1 = 4^2 \times V_2$

$V_2 = 9V_1 \quad ...(ii)$

From equation (i) and (ii)

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

$$\Rightarrow \frac{28\times10^3}{700}=\frac{80V_1^2}{2\times10}$$

$$\Rightarrow V_1^2=1m^2/s^2$$

$$\Rightarrow V_1=1m/s$$

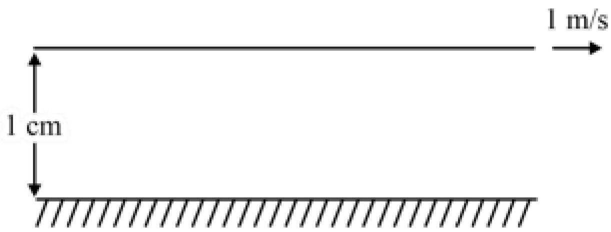
$$\dot{m}=700\times\frac{\pi}{4}\times(0.12)^2\times1$$

= 7.91 kg/s

[NAT-2]

Q.12. Consider two parallel plates separated by distance of 1 cm filled with a Newtonian fluid of viscosity 10^{-3} Pa.s. The top plate is moving with a velocity of 1 m/s whereas the bottom plate is stationary. The shear stress (in Pa, round off to 1 decimal place) on the top plate is _______.

Sol. **(0.1)**



$$\tau=\mu\frac{du}{dy}$$

$$\tau=10^{-3}\times\frac{1-0}{10^{-2}}$$

$$\tau=0.1Pa$$

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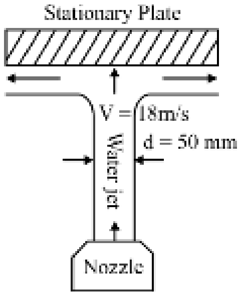
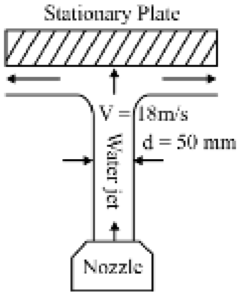
[NAT-2]

Q.13. A circular water jet of diameter 50 mm impinges with a velocity of 18 m/s normal to a plate. The density of water is 1000 kg/m^3 and gravity force is neglected.



The magnitude of at net force (in N, round off to 2 decimal place) imparted by the jet on the stationary plate is _____.

Sol. **(636.17)**



$F = \rho A V^2$

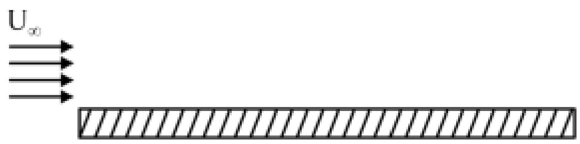
$= 1000 \times \frac{\pi}{4} \times 0.05^2 \times 18^2$

$= 636.17\,N$

[NAT-2]

Q.14. Consider the incompressible fluid flow over a flat plate with a free stream velocity $U_\infty = 1 m/s$. The fluid kinematic viscosity is $10^{-6} m^2/s$ and density is $1 kg/m^3$. The velocity profile with the boundary layer at any location x is given by $u(y) = U_\infty\left(\frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\frac{y^2}{\delta^2}\right)$, where boundary layer thickness $\delta = \frac{4.64x}{\sqrt{Re_x}}$. The local wall shear stress at x = 1m from the leading edge is _____ $\times 10^{-3} N/m^2$ (round off to 2 decimal place)

Sol. **(0.3233)**



$$\frac{u}{U_\infty} = \left(\frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\frac{y^2}{\delta^2}\right), \quad \delta = \frac{4.64x}{\sqrt{Re_x}}$$

$$Re_x = \frac{U_\infty \times x}{\nu} = \frac{1 \times 1}{10^{-6}} = 10^6$$

$$\delta = \frac{4.64 \times 1}{\sqrt{10^6}} = 4.64 \times 10^{-3} m$$

$$\left.\frac{du}{dy}\right|_{y=0} = U_\infty \times \frac{3}{2} \times \frac{1}{\delta} - 0 = \frac{3U_\infty}{2\delta}$$

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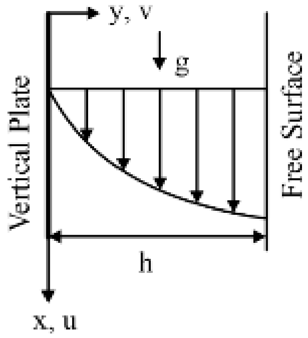
$$\tau|_{y=0} = \mu \frac{du}{dy}\bigg|_{y=0}$$

$$\tau_w = 10^{-6} \times 1 \times 1 \times \frac{3}{2} \times \frac{1}{4.64 \times 10^{-3}}$$

$$\tau_w = 0.3233 \text{Pa}$$

[MCQ-2]

Q.15. A thin film of an incompressible, Newtonian liquid (density ρ, viscosity μ) with an uniform thickness (*h*) is flowing down on a vertical plate. The flow is driven by gravity (g) alone. Assume zero shear stress condition at the free surface.



The maximum velocity is given by.

(a) $\frac{1}{2\mu}\rho g h^2$

(b) $\frac{1}{\mu}\rho g h^2$

(c) $\frac{1}{4\mu}\rho g h^2$

(d) $\frac{1}{8\mu}\rho g h^2$

Sol. **(a)**

$$v = 0; \quad \nabla P = 0$$

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

Applying Navier-Stokes Equation in x – direction

$$\Rightarrow \rho(g) + \mu\left\{\frac{d^2u}{dy^2}\right\} = \left\{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y}\right\}$$

$$\Rightarrow \frac{d^2u}{dy^2} = -\frac{\rho g}{\mu}$$

$$\Rightarrow u = -\frac{\rho g}{\mu} \times \frac{y^2}{2} + c_1 y + c_2$$

At $y = 0$; $u = 0$; $\Rightarrow C_2 = 0$

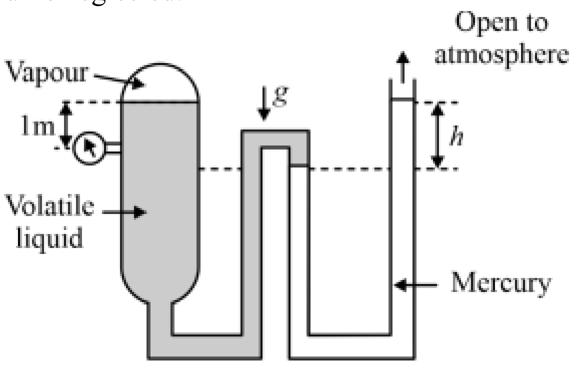
At $y = h$; $\frac{du}{dy} = 0 \Rightarrow C_1 = \frac{\rho g h}{\mu}$

$$\therefore u = \frac{\rho g}{\mu}\left[hy - \frac{y^2}{2}\right]$$

$$u_{max} = u|_{y=h} = \frac{\rho g}{\mu}\left[h^2 - \frac{h^2}{2}\right] = \frac{1}{2\mu}\rho g h^2$$

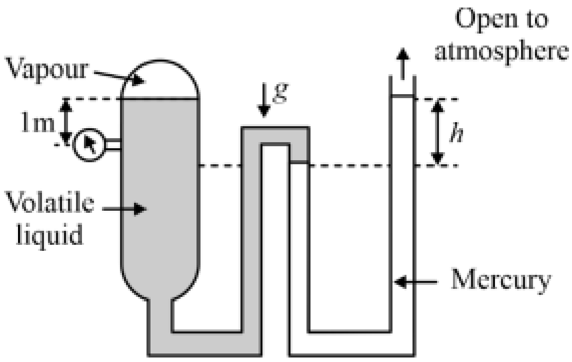
[NAT-2]

Q.16. A vessel which contains a volatile liquid, and its vapour is connected with a mercury manometer as shown in figure. Both the liquid and vapour phases are at equilibrium. The vapour pressure and density of volatile liquid is 107.6 kPa and 700 kg/m^3, respectively. The density of the mercury is 13600 kg/m^3, acceleration due to gravity is 10 m/s^2 and atmospheric pressure is 101 kPa. Hydrostatic pressure created by the weight of vapour is neglected.



The height h (in m, round off to two decimal place) of the mercury column in figure is ______.

Sol. **(0.1)**



From column balance

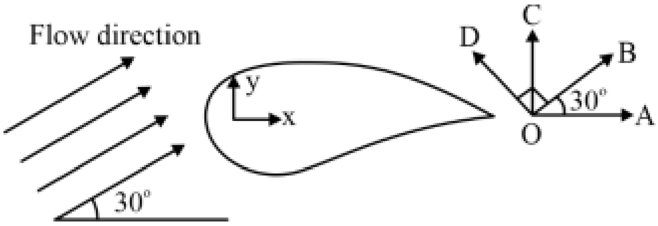
$$0+(\rho g)_{Hg}\times h-1\times(\rho g)_L=P_v$$

$$13600\times10\times h-700\times10=6.6\times10^3$$

$$h=0.1m$$

[MCQ-2]

Q.17. Consider a fluid flow around an airfoil as shown in figure.



The direction of drag force and lift force respectively are along.

(a) OB and OD
(b) OA and OC
(c) OA and OD
(d) OB and OC

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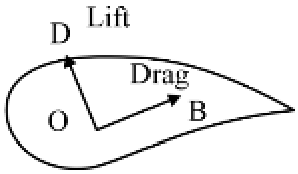
Sol. **(a)**



[MCQ-2]

Q.18. A set of basic dimensions mass, length, and time are represented by M, L, and T, respectively. What will be the dimensions of pressure in M-L-T system

(a) MLT^{-1}
(b) $ML^{-1}T^{-2}$
(c) $ML^{-1}T^{-1}$
(d) MLT^{-2}

Sol.18. **(b)**

$$\frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$$

[NAT-2]

Q.19. The axial velocity profile of a laminar, in compressible and fully developed flow in a circular Pipe of radius (R) is given as $u_z = \frac{-1}{4\mu}\frac{\partial P}{\partial z}R^2\left(1-\frac{r^2}{R^2}\right)$, where r, z, μ and P are radial direction, axial direction fluid viscosity and pressure respectively. It the average velocity of the flow is given by $u_{z,avg} = \frac{1}{k}\left(\frac{-R^2}{\mu}\frac{\partial P}{\partial z}\right)$, then the value of k (in integer) is ________.

Sol.19. **(8)**

$$u = -\frac{1}{4\mu}\left(\frac{\partial P}{\partial z}\right)R^2\left[1-\frac{r^2}{R^2}\right] = U_{max}\left[1-\frac{r^2}{R^2}\right]$$

$$U_{max} = -\frac{1}{4\mu}\frac{\partial P}{\partial z}R^2$$

$$U_{avg} = \frac{U_{max}}{2}$$

$$U_{avg} = \frac{1}{8\mu}\left(-\frac{\partial P}{\partial z}\right)R^2 = \frac{1}{k}\left(\frac{-R^2}{\mu}\frac{\partial P}{\partial z}\right)$$

$$\Rightarrow k = 8$$

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[MCQ-2]

Q.20. A one-eighth scale model of a car is to be tested in a wind tunnel. If the air velocity over the car is 16 m/s, what should be the air velocity (in m/s) in the wind tunnel in order to achieve similarity between the model and the prototype?

(a) 64
(b) 128
(c) 2
(d) 16

Sol.20. (b)

$L_r = 1/8$ $\qquad V_P = 16 m/s$

$(Re)_m = (Re)_P$

$$\left(\frac{\rho VD}{\mu}\right)_m = \left(\frac{\rho VD}{\mu}\right)_P$$

$$\frac{\rho_m}{\rho_P} = 1 \qquad \frac{\mu_m}{\mu_P} = 1$$

$V_m D_m = V_P D_P$

$$V_m = V_P \frac{D_P}{D_M} = \frac{16}{\frac{1}{8}} = 16 \times 8 = 128 m/s$$

[NAT-2]

Q.21. The velocity potential function in a two-dimensional flow fluid is given by ϕ (x, y) = – (axy + bx^2 – by^2) m^2/s, where a = 2 per second and b = 0.5 per second. The magnitude of the velocity (in m/s, in integer) at x = 2m, y = 1 m is _______.

Sol. **(5)**

$\phi(x, y) = -(axy + bx^2 - by^2)$

a = 2

b = 0.5

V = ?

x = 2m

y = 1m

$$u = -\frac{\partial\phi}{\partial x} = ay + 2bx$$

u = 2 × 1 + 2 ×0.5 × 2

u = 4m/s

$$v = -\frac{\partial\phi}{\partial y} = ax - 2by$$

= 2 × 2 – 2 × 0.5 × 1

= 4 – 1

v = 3m/s

$$V = \sqrt{u^2 + v^2} = \sqrt{4^3 + 3^2}$$

V = 5 m/s

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[NAT-2]

Q.22. The velocity in a one-dimensional flow is given by $u(x)=\dfrac{a}{(b-x)^2}$ m/s, where $a=8\,\text{m}^3/\text{s}$ and b = 4 m. The acceleration (in m/s^2, in integers) at x = 2m is _____.

Sol. **(4)**

$$u_x = \frac{a}{(b-x)^2}$$

$$u_x = u\frac{\partial u}{\partial x}$$

$$= \frac{a}{(b-x)^2}\times\frac{a(-2)}{(b-x)^3}(-1)$$

$$= \frac{3a^2}{(b-x)^5} = \frac{2\times(8)^2}{(4-2)^5} = \frac{2\times 64}{32}$$

$$a_x = 4\,\text{m/s}^2$$

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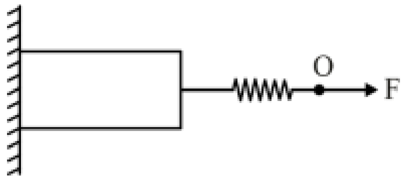
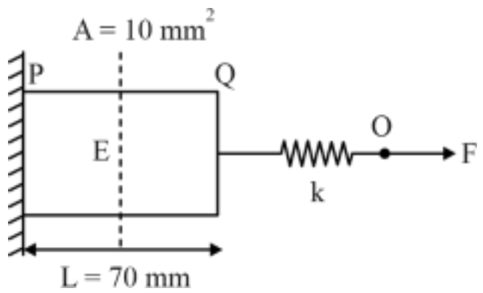
XE- D	Solid Mechanics

[NAT-1]

Q.1. A spring is connected to an elastic bar as shown in figure. The spring has a spring constant of 10^7 N/m. The length of bar is 70 mm, and the cross-section area of the bar is 10 mm^2. The young modulus of the bar material is 70000 MPa and a force F = 5000 N is applied at point O along the axis of bar and spring. The resulting deflection of point O in mm (Round of to one decimal place) is ______



Sol. **(1.0)**



$k = 10^7$ N/m = 10,000 N/m

E = 70,000 MPa

F = 5000 MPa

Elongation of point O

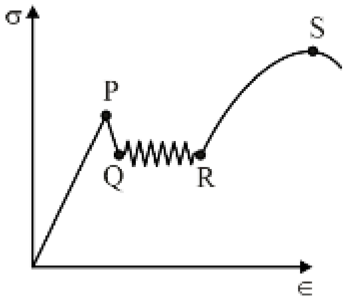
$\delta_o = \delta_{PQ} + \delta_{spring}$

$= \dfrac{5000 \times 70}{10 \times 70000} + \dfrac{5000}{10000}$

$= 1$ mm

[MCQ-1]

Q.2. The engineering Stress (σ) vs engineering strain ($\in$) obtained by conducting uniaxial tension test on a steel specimen is shown in figure (The sketched curve is not to the scale). The specimen exhibits cup & cone failure with its gage length. Which point on the curve correspond to beginning of necking in specimen?



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(a) S (b) R
(c) P (d) Q

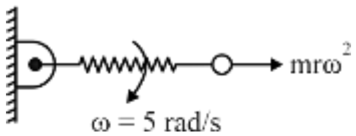
Sol. **(a)**

At point S, necking is starting.

[NAT-1]

Q.3. A particle of mass 1 kg is attached at one end of spring having spring constant k = 125 N/m. The free length of spring is 100 mm. System is rotated about other end of spring at uniform angular velocity of 5 rad/s. Ignore gravity and consider elongation of spring may be comparable to free length of spring. The elongation of spring (in mm, round off to nearest integer) is ________

Sol. **(20.80)**



Force acting on spring

$F = mr\omega^2 = 1 \times 0.1 \times 5^2 = 2.5$ N

Elongation of spring

$$x = \frac{F}{k} = \frac{2.5}{125} = 0.0208 \text{ m}$$

x = 20.80 mm

[MCQ-1]

Q.4. An ice skater starts spinning during her performance. As she retracts her arms and legs closer to her body, her angular velocity.

(a) goes to zero (b) increases
(c) decreases (d) remain same

Sol. **(b)**

When the ice skater retracts her arms and legs closer to her body, the total mass moment of inertia will decrease, hence her angular velocity will increase.

[MSQ-1]

Q.5. A solid circular shaft of diameter 100 mm is subjected to a torque of 3π kN-m. Which of following statements about state of stress in shaft is/are correct?

(a) Magnitude of shear stress is 48 MPa at all points in the shaft.
(b) The maximum shear stress is 48 MPa.
(c) Magnitude of maximum compressive stress is 48 MPa.
(d) The maximum tensile stress is 48 MPa.

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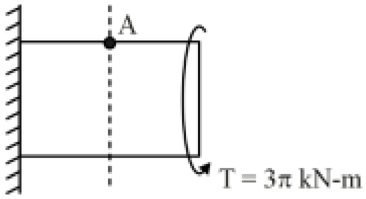
Sol. **(b, c, d)**

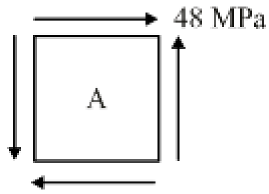


$T = 3\pi \times 10^6$ N-mm

$$\tau_{max} = \tau_{T,\,A} = \frac{16T}{\pi D^3} = \frac{16 \times 3\pi \times 10^6}{\pi \times 100^3}$$

$= 48$ MPa

Point A is in pure shear,

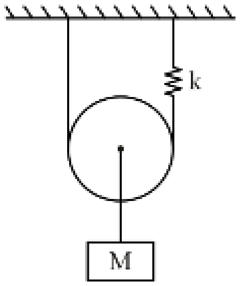


$\therefore \left|\sigma_{c,\,max}\right| = \left|\sigma_{t,\,max}\right| = 48$ MPa

Option b, c and d are correct.

[MCQ-1]

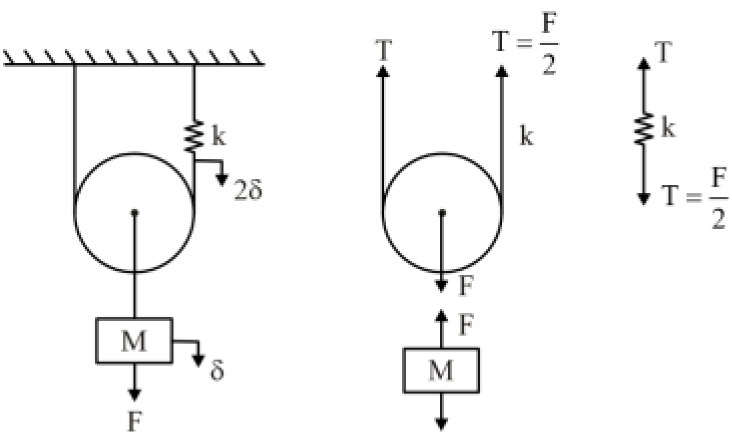
Q.6. A mass M is hung from a frictionless, massless pulley. Pulley is suspended by using an inextensible, massless rope of which one end is directly fixed to a support and other end is connected to support through a linear spring of stiffness constant k (see figure). The natural frequency of the system is



(a) $\sqrt{\frac{4k}{M}}$ (b) $\sqrt{\frac{k}{2M}}$

(c) $\sqrt{\frac{k}{M}}$ (d) $\sqrt{\frac{2k}{M}}$

Sol. **(a)**



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By equivalent stiffness method

$$k_e = \frac{F}{\delta}$$

Deflection of spring = 2δ

$$\Rightarrow \frac{F/2}{k} = 2\delta$$

$$\Rightarrow \frac{F}{\delta} = 4k$$

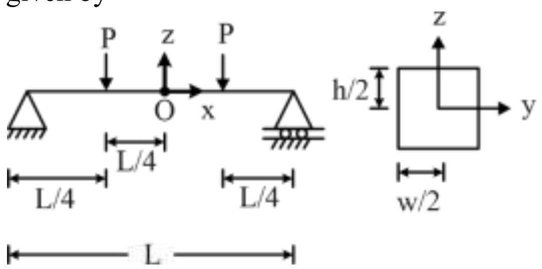
$$\Rightarrow k_e = 4k$$

Therefore, natural frequency of the system

$$\omega = \sqrt{\frac{k_e}{m}} = \sqrt{\frac{4k}{m}}$$

[MCQ-1]

Q.7. A simply supported beam of rectangular cross section (width w and height h) is subjected to loads as shown in figure (i). The enlarged view of beam cross-section is shown in figure (ii). The coordinate system is indicated in the figure. Assuming Euler Bernoulli theorem approximation, the shear stress τ_{xz} and normal stress σ_{xx} at origin O are respectively given by



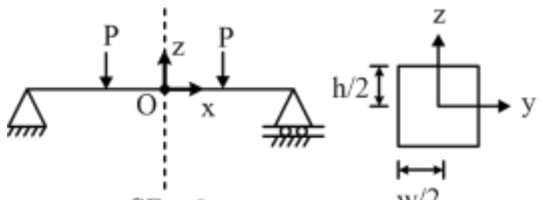
(a) 0, 0

(b) $\frac{3P}{2wh}$, 0

(c) 0, $\frac{3PL}{2wh^2}$

(d) $\frac{3P}{2wh}$, $\frac{3PL}{2wh^2}$

Sol. **(a)**



SF = 0

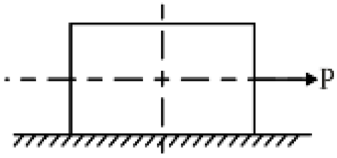
$\therefore \tau_{xz}|_o = 0$

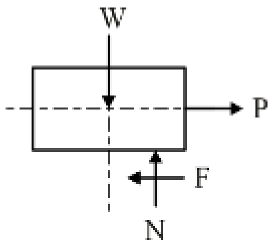
Since Point O is at neutral axis,

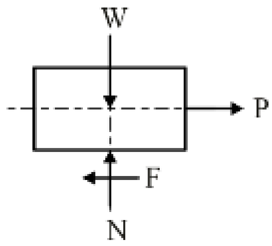
$\therefore \sigma_{xx}|_o = 0$

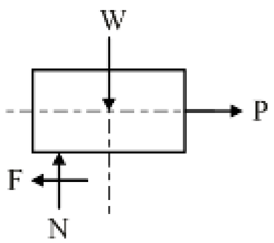
[MCQ-1]

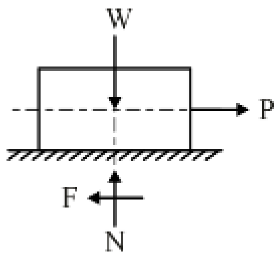
Q.8. A block weight of W is placed on a surface is subjected to a horizontal force P as shown in figure. The line of action of force P passes through the centre of gravity of block. The magnitude P is such that block remains at rest. If N is the resultant normal reaction exerted by surface and F is frictional force acting on bottom surface of block, then which of the following represent correct free body diagram of the block?



(a) 

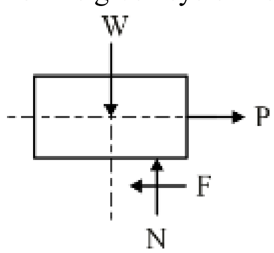
(b) 

(c) 

(d) 

Sol. **(a)**

Correct free body diagrams for the given system is shown below.



[MCQ-1]

Q.9. A L shaped rigid member is fixed at midpoint of simply supported beam, as shown in figure (i). The member is subjected to a vertically downward force P at its free end. In an equivalent system the member along with the applied load is replaced with a force Q = P and a moment M (see figure ii). Which of the following statement is correct?

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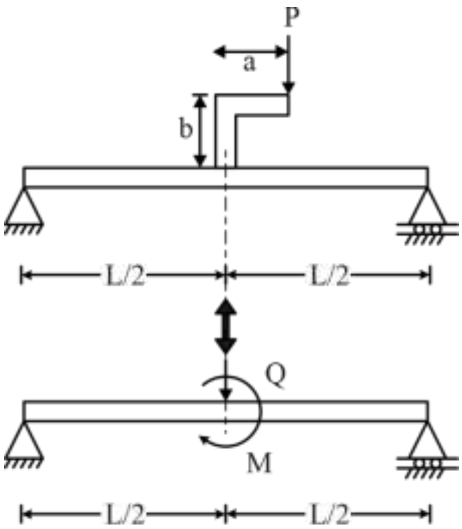
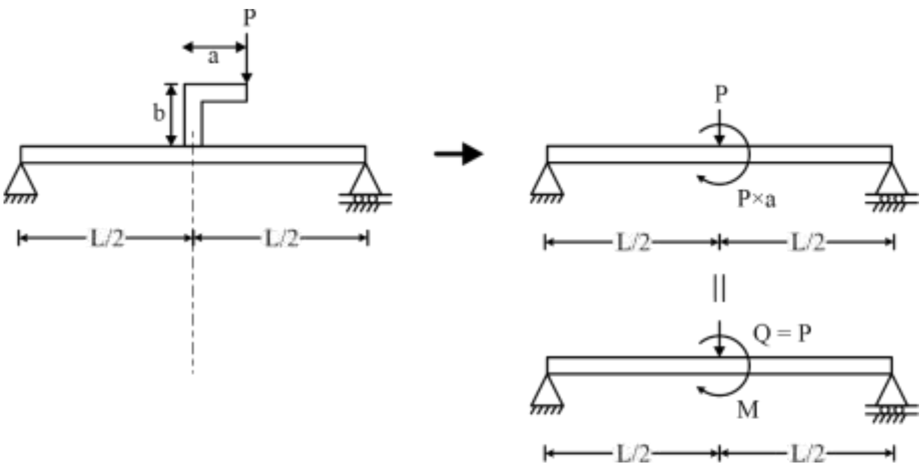


(a) M = 0 (b) M = Pa

(c) M = Pb (d) M = (a + b)

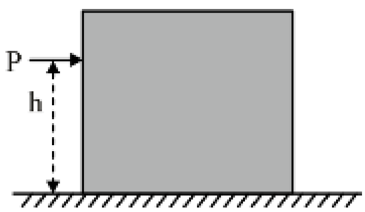
Sol. **(b)**



∴ Moment M = Pa

[NAT-2]

Q.10. A square block of side 1 m and mass 10 kg is resting on horizontal surface. The coefficient of static friction between the block and the surface is 0.75. The horizontal force P is gradually increased zero until block either slides or topples. The maximum value of h (in m, round off to two decimal places) for which block slider without toppling is ______. $g = 10\ m/s^2$



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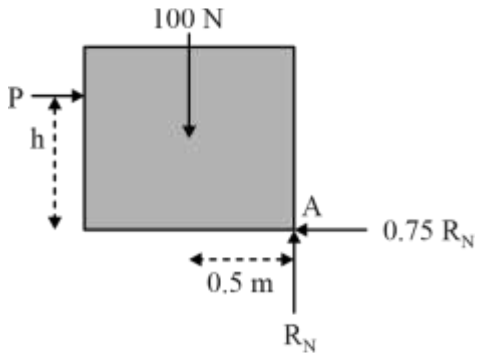
Sol. **(0.67)**



$\Sigma F_y = 0$

$\Rightarrow R_N = 100$ N

$\Sigma F_x = 0$

$\Rightarrow P = \mu \times R_N = 0.75 \times 100 = 75$ N

$\Sigma M_A = 0$

$\Rightarrow P \times h = 100 \times 0.5$

$\Rightarrow 75 \times h = 50$

$\Rightarrow h = 0.67$ m

[MSQ-2]

Q.11. A critical point on a component is subjected to the state of stress (σ) as given in the following. The yield strength of material is 400 MPa. By considering maximum shear stress (Tresca's) theory, the possible value(s) of σ_0 at onset of yielding is/are

$$[\sigma] = \begin{bmatrix} 280 & 0 & 0 \\ 0 & \sigma_0 & 0 \\ 0 & 0 & -60 \end{bmatrix} \text{MPa}$$

(a) 340 (b) –120

(c) 680 (d) 460

Sol. **(a, b)**

$\sigma_1 = 280$ MPa, $\sigma_2 = \sigma_0$, $\sigma_3 = -60$ MPa

$S_{yt} = 400$ MPa

At start of yielding as per maximum shear stress theory

$\tau_{max} = 0.5\, S_{yt} = 0.5 \times 400 = 200$ MPa

Check by option

(a) $\sigma_2 = \sigma_0 = 340$ MPa

$\sigma_{math,\,max} = 340$ MPa

$\sigma_{math,\,min} = -60$ MPa

$$\tau_{max} = \frac{\sigma_{math,\,max} - \sigma_{math,\,min}}{2} = \frac{340-(-60)}{2}$$

$\Rightarrow \tau_{max} = 200$ MPa, $\Rightarrow$ yielding start

$\therefore$ option a is correct

(b) $\sigma_2 = \sigma_0 = -120$ MPa

$\sigma_{math,\ max} = 280$ MPa

$\sigma_{math,\ min} = -120$ MPa

$$\tau_{max} = \frac{\sigma_{math,\ max} - \sigma_{math,\ min}}{2} = \frac{280-(-120)}{2}$$

$\Rightarrow$ $\tau_{max} = 200$ MPa, $\Rightarrow$ yielding start

Option b is also correct

(c) $\sigma_2 = \sigma_0 = 680$ MPa

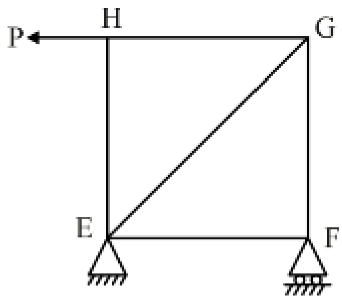
No need to check because when σ_0 is positive it can not be more then 340 MPa because at 340 MPa, because at 340 MPa yielding is starting.

(d) $\sigma_2 = \sigma_0 = 460$ MPa

No need to check because when σ_0 is positive it can not be more then 340 MPa because at 340 MPa, because at 340 MPa yielding is starting.

[MCQ-2]

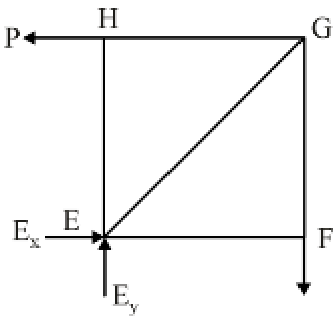
Q.12. A pin jointed truss has a pin support at point E and roller support at point F. A horizontal force P is applied at pin H as shown in figure. Which one of the member is in compression?



(a) EG (b) FG

(c) EH (d) EF

Sol. **(a)**



From above diagram it is clear that EF and EH are zero force members.

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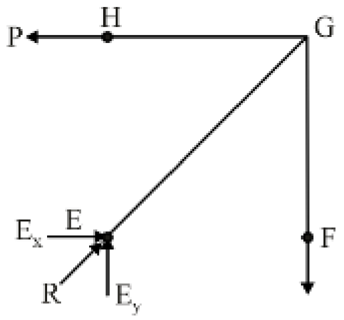
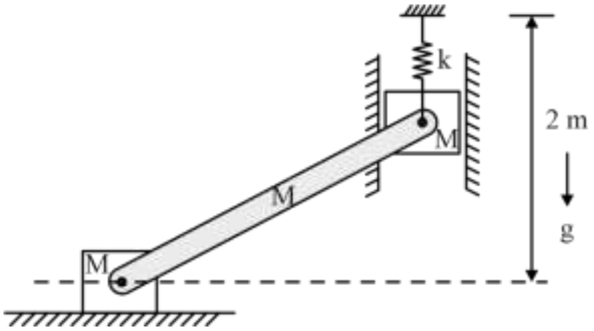


(R is the resultant of E_x and E_y)

It is clear from the diagram that HG and FG are in tension and EG is in compression.

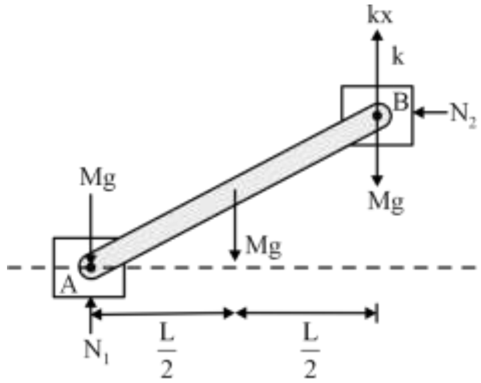
[NAT-2]

Q.13. The system shown in figure is in static equilibrium. The spring is massless and has spring constant k = 1 kN/m. The free length of spring is 1 m. All bodies in system except spring are rigid and have mass of M = 1 kg. All surfaces are frictionless and pin-joints are ideal. The elongation of spring (in mm. Rounded off to nearest integer) in this (on figuration) in this configuration is ______. take $g = 10\ m/s^2$



Sol. **(15)**

Free body diagram of the system shown below



$\Sigma M_B = 0$

$\Rightarrow N_1 \times L - Mg \times L - Mg\frac{L}{2} = 0$

$\Rightarrow N_1 = 15\ N$

$\Sigma F_y = 0$

$\Rightarrow N_1 + kx = 3Mg$

$\Rightarrow 15 + 1000x = 30$

$\Rightarrow x = 15 \times 10^{-3}\ m = 15\ mm$

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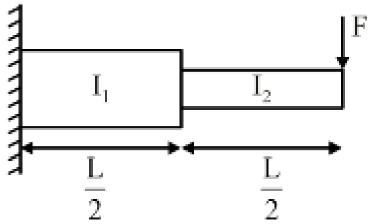
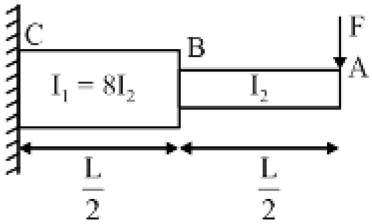
Engineering Science (XE)

[NAT-2]

Q.14. A stepped beam is made of material whose young modulus is E. In the stepped beam the moment of inertia of first portion (I_1) is eight times of moment of inertia of second portion (I_2). Under this loading condition, if strain energy of steeped beam is $U=\frac{\beta F^2L^3}{EI_1}$, then value of β ________ (Round off to two decimal places)



Sol. **(0.31)**



Strain energy of the stepped beam

$$U = U_{AB} + U_{BC}$$

$$\Rightarrow U = \int_0^{L/2}\frac{(Fx)^2dx}{2EI_2} + \int_{L/2}^{L}\frac{(Fx)^2dx}{2EI_1}$$

$$\Rightarrow U = \frac{F^2}{2E\left(\frac{I_1}{8}\right)}\left[\frac{x^3}{3}\right]_0^{L/2} + \frac{F^2}{2EI_1}\left[\frac{x^3}{3}\right]_{L/2}^{L}$$

$$\Rightarrow U = \frac{4F^2}{3EI_1}\left[\frac{L^3}{8}-0\right] + \frac{F^2}{6EI_1}\left[L^3-\frac{L^3}{8}\right]$$

$$\Rightarrow U = \frac{4F^2L^3}{24EI_1} + \frac{7F^2L^3}{48EI_1} = \frac{15}{48}\frac{F^2L^3}{EI_1}$$

$$\Rightarrow \frac{\beta F^2L^3}{EI} = \frac{15}{48}\frac{F^2L^3}{EI_1}$$

$$\Rightarrow \beta = \frac{15}{48} = 0.3125$$

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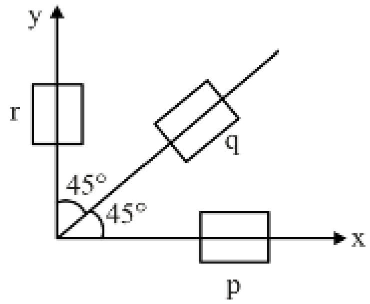
[MCQ-2]

Q.15. A 0-45-90 strain gauge rosette is mounted on an aircraft wing. The coordinate system is placed such that the strain gauge p, q and r are oriented at angles 0°, 45° and 90° respectively from x axis (see figure). The strain associated to p, q and r denoted by ϵ_p. ϵ_q and ϵ_r respectively. While conducting a test the strain gauge shows the following reading. $\epsilon_p = 150 \times 10^{-6}$, $\epsilon_q = 180 \times 10^{-6}$, $\epsilon_r = -90 \times 10^{-6}$.
The developed engineering shear strain γ_{xy} associated to strain gauge data is



(a) 120×10^{-6}
(b) 300×10^{-6}
(c) 240×10^{-6}
(d) 180×10^{-6}

Sol. **(b)**

$$\varepsilon_\theta = \left(\frac{\varepsilon_x + \varepsilon_y}{2}\right) + \left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)\cos 2\theta + \frac{\gamma_{xy}}{2}\sin 2\theta$$

$$\text{At } \theta = 45°,\ \varepsilon_q = 180 \times 10^{-6}$$

$$\varepsilon_x = \varepsilon_p = 150 \times 10^{-6}, \varepsilon_y = \varepsilon_r = -90 \times 10^{-6}$$

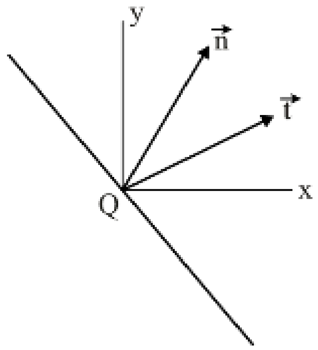
$$\Rightarrow 180 = \left(\frac{150 - 90}{2}\right) + 0 + \frac{\gamma_{xy}}{2}$$

$$\Rightarrow 360 = 60 + \gamma_{xy}$$

$$\Rightarrow \gamma_{xy} = 300 \times 10^{-6}$$

[NAT-2]

Q.16. A plane passing through point Q inside a body is shown. The unit normal of the plane is $\hat{n} = 0.6\hat{i} + 0.8\hat{j}$ as shown in figure. The traction (stress) vector on plane at point Q is given by stress $\vec{t} = (50\hat{i} + 20\hat{j})$ MPa. Given that at point Q, $\sigma_{xx} = \sigma_{yy}$. The shear stress component τ_{xy} (in MPa, round off to two decimal places) is ________



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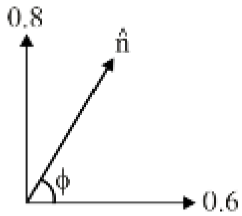
Sol. **(100)**

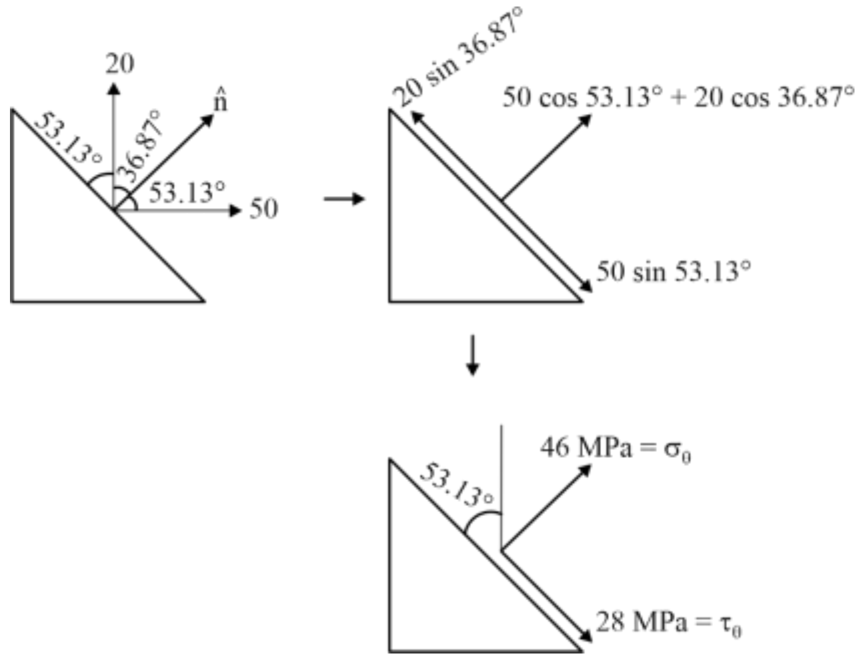
$\hat{n} = 0.6\hat{i} + 0.8\hat{j}$



$\tan\phi = \frac{0.8}{0.6}$

$\Rightarrow \phi = 53.13°$

$\vec{t} = (50\hat{i} + 20\hat{j})$ MPa



Given: $\sigma_{xx} = \sigma_{yy}$

$\tau' = -\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$

$\tau'_\theta - 28$ MPa $\rightarrow \theta = 53.13$ and $\sigma_{xx} = \sigma_{yy}$

$\Rightarrow -28 = 0 + \tau_{xy}\cos(2 \times 53.136)$

$\Rightarrow \tau_{xy} = 100$ MPa

[NAT-2]

Q.17. A turn table is rotating about its centre with an angular velocity of 2 rad/s in counter clockwise direction. There is a groove in turn table within which a marble moves with a constant speed v m/s relative to turn table. At given instant the value of v (in m/s, Round off to one decimal place) for which there is no radial acceleration for marble at this instant is _______.

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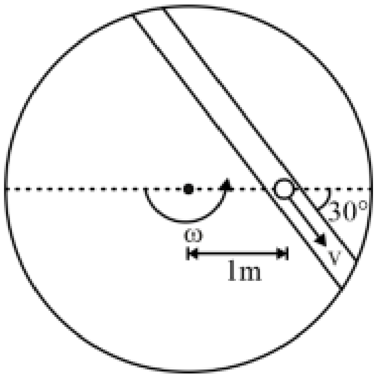
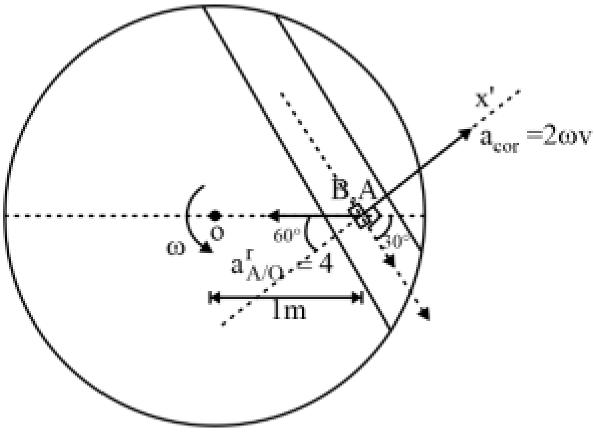


Sol. **(0.5)**



$V = V_{\text{marble/turning table}}$

$\left.a_B\right)_{radial} = \left.a_B\right)_{x'} = 0$

$\vec{a}_B = \vec{a}_{B/A} + \vec{a}_{B/O}$ .....(i)

Here,

$\vec{a}_{B/A} = \vec{a}_{cor} = 2\omega V$

$\vec{a}_{A/O} = a^r_{A/O} = \omega^2 \times OA = 2^2 \times 1 = 4 m/s^2$

Resolving (i) in x' direction

$\left.\vec{a}_B\right)_{x'} = \left.\vec{a}_{B/A}\right)_{x'} + \left.\vec{a}_{B/O}\right)_{x'}$

$\Rightarrow 0 = 2\omega V - 4\cos 60$

$\Rightarrow 2\omega V = 4\cos 60$

$\Rightarrow 2 \times 2 \times V = 4 \times 0.5$

$\Rightarrow V = 0.5 m/s$

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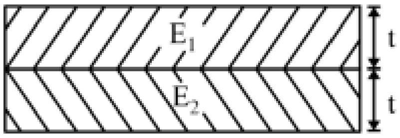
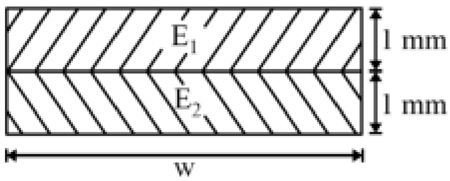
[MCQ-2]

Q.18. A beam of rectangular cross section as shown in figure is made of two perfectly bonded layers of different materials and equal thickness. The beam is subjected to pure bending. If t = 1 mm, the distance of neutral plane from top surface of beam is _____ mm (Round off to two decimal places)



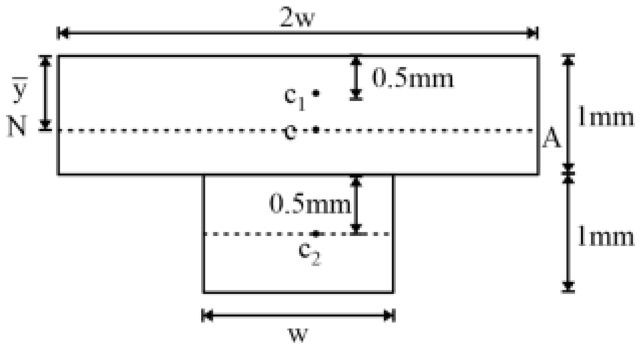
Given $E_1 = 2E_2$

Sol. **(0.83)**



$$m = \frac{E_1}{E_2} = \frac{2E_2}{E_2} = 2$$

Equivalent width of 1st material = m × w = 2w



$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$$

$$\bar{y} = \frac{2w \times 1 \times 0.5 + w \times 1 \times 1.5}{2w \times 1 + w \times 1}$$

$$\bar{y} = 0.83 \text{mm}$$

[NAT-2]

Q.19. A cylindrical vessel is constructed by bolting two symmetric halves of flanged semi cylindrical and shells. A cross sectional view is shown in figure. The inner diameter of vessel is 2 m and length is 10 m. Each row comprises 100 bolts along length of vessel. If vessel is pressurised to a net pressure of 6×10^5 N/m^2 and assuming end caps do not take any load in radial direction. The load borne by each bolt is _________ (in kN, Round off to one decimal place)

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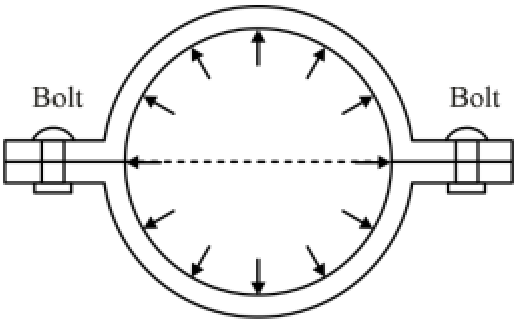
Sol. **(60)**



Total force on bolts in longitudinal direction

$\sum F_y = p \times \ell d$

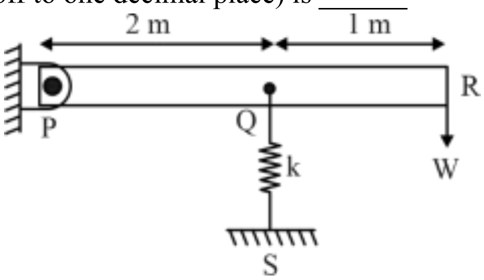
$\sum F_y = 6 \times 10^5 \times 10 \times 2 = 120 \times 10^5\, N$

Force on each bolt = $\dfrac{120 \times 10^5}{200}$ = $60 \times 10^3 N$

= 60 kN

[NAT-2]

Q.20. A rigid massless bar PQR is hinged at its end P and supported through a spring of stiffness k at point Q. A vertical downward force W = 560 N is applied at free end R of bar. If vertical component of displacement at R is 30 mm, then the stiffness of spring (in kN/m, Round off to one decimal place) is ______



Sol. **(42.0)**

Given: y_R = 30 mm, k = ?

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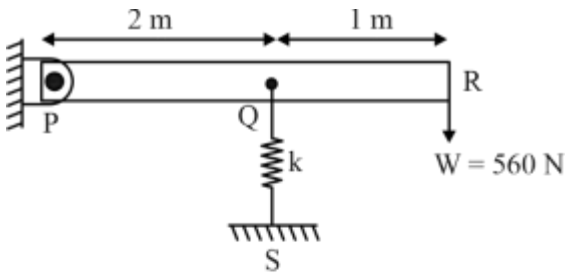
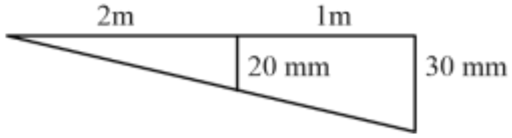




$\Sigma M_P = 0$

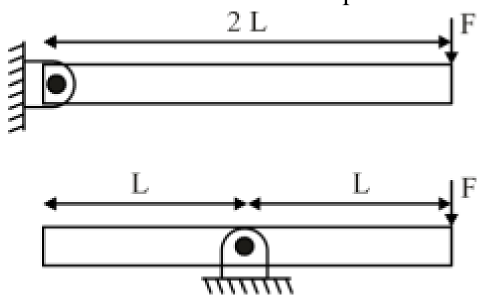
$\Rightarrow$ kx × 2 = 560 × 3

$\Rightarrow$ k × 20 × 2 = 560 × 3

$\Rightarrow$ k = 42 N/mm = 42 kN/m

[MCQ-2]

Q.21. Two identical rigid slender bars of length 2L and mass m are acted upon by a transverse force F at one of ends as shown. What should be magnitude of force F such that resulting angular acceleration of two bars are equal

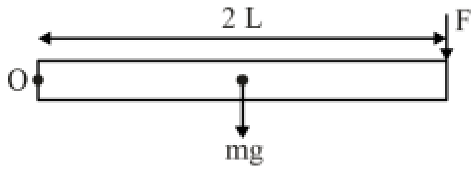


(a) $\frac{mg}{6}$ (b) mg

(c) $\frac{mg}{2}$ (d) $\frac{mg}{4}$

Sol. **(c)**

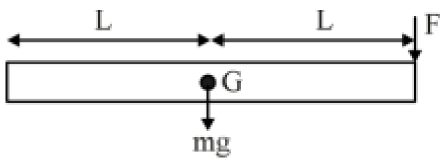
FBD for case I



$\Sigma M_o = I_o\alpha$

$$\Rightarrow F \times 2L + mg \times L = \frac{m(2L)^2}{3}\alpha \qquad \ldots(1)$$

FBD for case II



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$$\Sigma M_G = I_G \alpha$$

$$\Rightarrow F \times L = \frac{m(2L)^2}{12}\alpha$$

$$\Rightarrow \alpha = \frac{3F}{mL}$$

From equation (1)

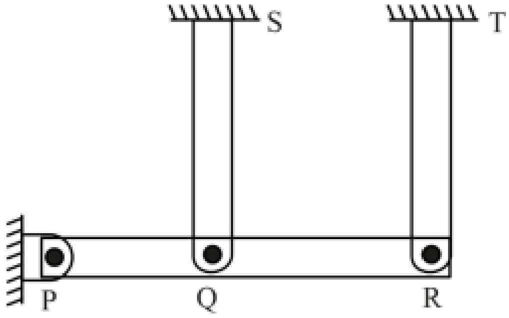
$$\Rightarrow F \times 2L + mg \times L = \frac{m(2L)^2}{3} \times \frac{3F}{mL}$$

$$\Rightarrow 2FL + mgL = 4FL$$

$$\Rightarrow F = \frac{mg}{2}$$

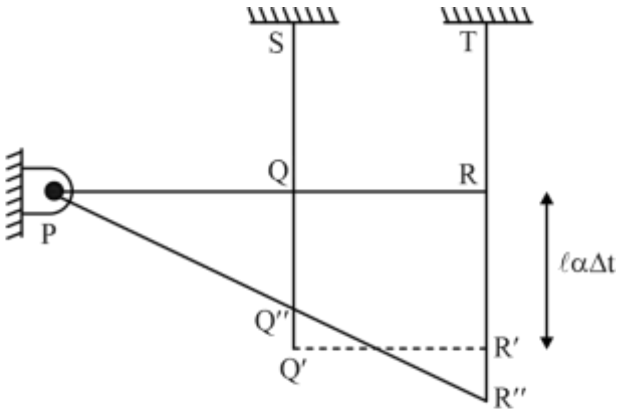
[MCQ-2]

Q.22. A rigid bar PQR is hinged at its end P as shown. Links QS and TR are made of same material. If temperature of links uniformly increased by ΔT, then which one of following statements is correct? (Neglect weight of rigid bar)



(a) Both QS and RT will be under tension.
(b) Both QS and RT will be stress free.
(c) QS will be under compression and RT will be under tension.
(d) Both QS and RT will be under compression.

Sol. **(c)**



Due to ΔT, SQ and TR will elongate equally upto Q′ and R′ but as they should lie on the rigid, SQ will be compressed from Q′ to Q″ and TR will expand from R′ and R″. Hence,

$$\sigma_{QS} = \text{compressive}$$

$$\sigma_{TR} = \text{Tensile}$$

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XE- E	Thermodynamics

[MCQ-1]

Q.1. A rigid tank, initially at 1 bar 300 K, contains 5 moles O_2, 4 moles of N_2 and 3 moles of H_2. From this tank, 2 moles of O_2 are removed keeping the temperature constant. Assuming ideal gas behaviour, the final partial pressure of O_2 (in bar) inside the tank is ____ ***[Round off to the three decimal places]*** use R = 8.314 J/mol.k. Molecular weight of H_2 , N_2 and O_2 2 g/mol, 28 g/mol and 32 g/mol respectively.

Sol. **(25 kPa)**

State 1

1 bar
300 K
5 moles O_2 + 4 moles O_2 + 3 moles O_2

State 2
P_2
300 K
3 moles O_2 + 4 moles O_2 + 3 moles O_2

$$P_1V = \sum n\bar{R}T$$

$$100 \times V = \frac{(5 + 4 + 3)}{1000} 8.314 \times 300$$

V = .2993 MJ

$$P_2V = \sum n\bar{R}T$$

$$P_2 \times .2995 = \frac{(3+4+3)}{1000} 8.314 \times 300$$

P_2 = 83.33 kPa

$$P_{o2} = x_{o2}p$$

$$P_{o2} = \frac{3}{3+4+3} \times 83.33$$

$$\boxed{P_{o_L} = 25 \text{ kPa}}$$

[MCQ-1]

Q.2. Given v is the molar specific volume, P is the pressure, T is the temperature, R is the universal gas constant and a, b are Vander Waal's constant. The Vander Waal's equation of state is

$$P = \frac{RT}{v-b} - \frac{a}{v^2}$$

The value of $\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial T}{\partial P}\right)_v$ is:

(a) 1 (b) -1

(c) 0 (d) 0.5

Sol. **(b)**

By cyclic relation

$$\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial T}{\partial P}\right)_V = -1$$

[NAT-1]

Q.3. Following data is for an actual vapour compressor refrigeration cycle.

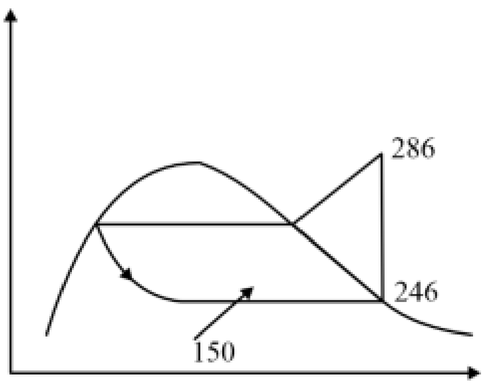
Enthalpy at compressor inlet = 246 kJ/kg

Enthalpy at compressor exit = 286 kJ/kg

Heat load on the evaporator = 150 kJ/kg

Enthalpy at the exit of the condenser in (kJ/kg) is ____ ***[Round off to the nearest integer]***

Sol. **(96)**



$h_1 = 246$ kJ/g

$h_2 = 286$ kJ/g

$Q_{load} = 150 \frac{kJ}{kj}$

$Q_{load} = h_1 - h_4$

$150 = 246 - h_4$

$h_4 = 96$

$h_3 = h_4 = 96$

[MCQ-1]

Q.4. The temperature of 10 gram of liquid water (C_P = 4.2 J/g.K) in an insulated container is raised 5 K by stirring. The amount of heat transferred to the water (in J) is

(a) 210 (b) 0

(c) 420 (d) 105

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Sol. **(b)**

As container is insulated so heat transfer is zero the temperature is increases because at work transfer.

[MSQ-1]

Q.5. A closed system containing an unknown substance undergoes an adiabatic process governed by the relation pv^{γ} = constant where P = Pressure, v = volume and γ is ratio of specific heats. For this scenario, which of the following statements is/are always ?

(a) The substance is liquid, and process is reversible

(b) The substance is non ideal gas and process is reversible

(c) The substance is an ideal gas and process is not reversible

(d) The substance is an ideal gas and process is reversible

Sol. **(d)**

$PV^{y} = C$ is ideal gas equation for reversible adiabatic process.

[MSQ-1]

Q.6. Two rigid impermeable containers A and B are filled with an ideal gas. They are allowed to exchange heat only with each other and not with the surroundings. P, V, N, T represents the pressure, total volume, number of moles and temperature respectively at equilibrium. Which of the following conditions is/are necessarily satisfied. Subscripts A and B represents properties of the gas in the respective container.

(a) $P_A = P_B$

(b) $\frac{P_A}{V_A} = \frac{P_B}{P_B}$

(c) $T_A = T_B$

(d) $\frac{P_A V_A}{N_A} = \frac{P_B V_B}{N_B}$

Sol. **(c and d)**

As the system finally reaches to thermal equilibrium

So

$T_A = T_B$

We know

$$P_A V_A = N_A \bar{R} T_A$$

$$T_A = \frac{P_A V_A}{N_A R}$$

$$P_B V_B = N_A \bar{R} T_B$$

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$$T_B = \frac{P_B V_B}{N_B \bar{R}}$$

$$T_A = T_B$$

$$\frac{P_A V_A}{N_A} = \frac{P_B V_B}{N_B}$$

[MCQ-1]

Q.7. A heat source at temperature T_H transfers the same amount of heat to a sink under the following situations

Case A: Sink is at temperature $T_{L,1}$

Case B: Sink at temperature $T_{L,2}$

If $T_{L,1} < T_{L,2}$, which one of the following statements is TRUE?

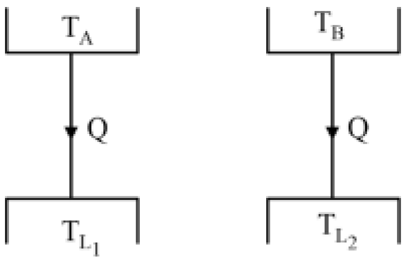
(a) Case B is less reversible with the entropy generation greater than zero

(b) Case B is more reversible with the entropy generation is greater than zero

(c) Case B is more reversible with the entropy generation equal to zero

(d) The reversibility is the same and the entropy generation is greater than zero for cases A and B

Sol. **(b)**



$$T_{L_1} < T_{L_2}$$

$$\left(T_A < T_{L_1}\right) > \left(T_A < T_{L2}\right)$$

We know

Heat transfer due to more temperature difference is more irreversible (less reversible) and entropy generation for any irreversible process is positive.

So case B is more reversible with entropy generation greater than zero.

[MCQ-1]

Q.8. A Power Plant operates on a simple ideal Rankine cycle if superheating is added to this cycle, then which one of the following options is correct?

(a) Pump work remain same, turbine work output increases, cycle efficiency increases and moisture content at turbine exit decreases

(b) Pump work remain same, turbine work output increases, cycle efficiency increases and moisture content at turbine exit increases

(c) Pump work increases, turbine work output increases, cycle efficiency increases and moisture content at turbine exit increases

(d) Pump work decreases, turbine work output increases, cycle efficiency increases and moisture content at turbine exit decreases

Sol. **(a)**

Force super heating

Pump work = same

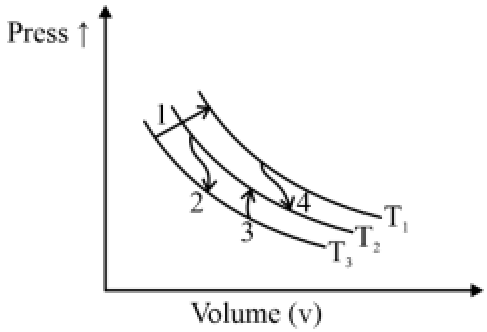
Turbine work = increases

Efficiency = increases

Moisture content = decreases

[MCQ-1]

Q.9. The figure shown four different processes labelled 1, 2, 3 and 4 for the same closed system, containing an ideal gas. The curved labelled. T_1, T_2 and T_3 are isotherms. For which one of these four processes the magnitude of internal energy change is the highest.



(a) Process 4 (b) Process 3

(c) Process 1 (d) Process 2

Sol. **(c)**

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[MCQ-2]

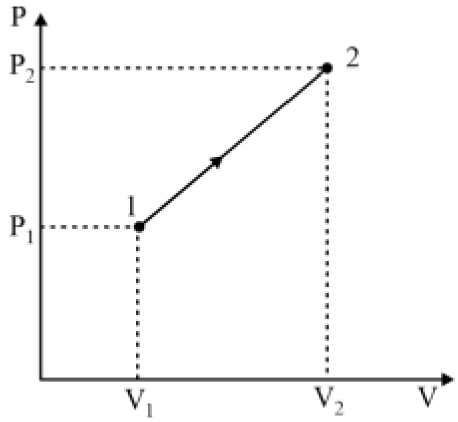
Q.10. A piston cylinder system contains 2 kg of wet steam at 90°C with quality of 0.1. The piston is loaded with linear spring the steam expands to 800 kPa and 250°C on heating. The work done in (kJ) in this process is _____ ***[Round off to the two decimal places]***

Use the following data:

At 90°C, P_{sat} = 70 kPa, v_f = 0.001 m^s/kg, v_g = 214 m^3/kg.

At 250°C and 800 kPa, v = 0.29 m^3/kg

Sol. **(232.89)**



P_1 = 70 kPa

P_2 = 800 kPa

$v_1 = v_f + x_1 (v_q - v_f)$

$= 0.001 + 0.1 (2.41 - 0.001)$

$= 0.2419$

$V_1 = mv_1$

$V_2 = 0.4838$

$V_2 = mv_2$

$= 0.58$

$$W = \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$$

$= 41.84$ kJ

[MCQ-2]

Q.11. 100 moles of moist air at 70% relative humidity are cooled from 70° C to 50° C at a constant pressure of 1 bar. The vapour pressure of water is given in the table. The number of moles of water left in the moist air at the end of this process is _______. ***[Round off to the two decimal places]***

Temperature (°C)	Vapour (kPa)
50	12.34
70	31.16

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Sol. **(11)**

ϕ = 70% humidity

$$\phi = \frac{P_V}{P_{vs}} \Rightarrow P_V = 0.7 \times 31.16$$

$P_V = 21.812$ kPa

Since

$P_a + P_v = 100$ kPa

$P_A = 100 - 21.812$

$= 78.182$ kPa

Final state

$T_1 = 50°C$

$P_{vs} = 12.34$ kPa

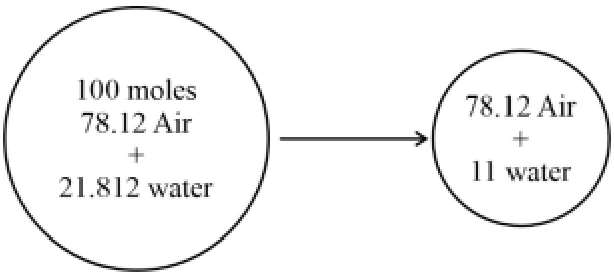
Since P_{vs} at state 2 is lower than P_V at state 1 condensation will take place. So P_V at final stage will be equal to P_{vs} which is equal to 12.34 kPa

Hence at final stage P_{Air} will be equal to 100 – 12.34 = 87.66 kPa

In final stage 87.66% of moels will be of air and 12.34 % moles will be of water. But out of initial 100 moles of moist air only 78.182 moles were of air only. So moles of water in final mixture

$$\frac{x}{78.182} = \frac{12.34}{87.66} = x = 11.00$$

Hence moles of water = 11



[NAT-2]

Q.12. Air assumed as an ideal gas with a mass flow rate of 2.5 kg/s enters a horizontal nozzle at 350 K, 350 kPa with a velocity of 3 m/s. The air exits the nozzle at a pressure of 101.5 kPa and temperature 305 K with a Mach number of 9/7. Assuming steady state operation and constant properties given in the data, the ratio of inlet area to exit area required to satisfy the exit condition is _____(correct up to one decimal). Use $\gamma = 1.4$, $c_p = 1.011$ kJ/kg.K, R = 0.287 kJ/kg.K

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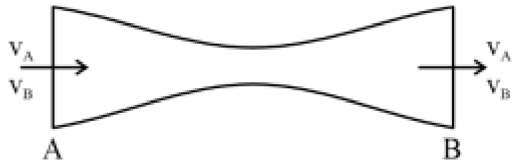
Sol. **(49.68)**



$V_a = 3$ m/s

$V_B = M_B.C_B = M_B = \sqrt{rRT_B}$

Using ideal gas as equation at (A)

$P_AV_A = m_ART_A$

$$V_A = \frac{m_ART_A}{P_A}$$

$$A_a = \frac{V_A}{v_A} \Rightarrow \frac{m_ART_A}{P_A.v_A}$$

$$A_B = \frac{m_BRT_B}{P_Bv_B}$$

$A_A = 3$ m/s

$$v_B = \frac{9}{7}\sqrt{1.4\times287\times305}$$

$$\frac{A_A}{A_B} = \frac{\frac{m_ART_A}{P_Av_A}}{\frac{m_BRT_B}{P_Bv_B}}$$

$$\Rightarrow \frac{T_A.P_B.v_B}{P_Av_{A.}T_B}$$

$$\Rightarrow \frac{350\times101\times\frac{9}{7}\sqrt{1.4\times287\times305}}{350\times3\times305}$$

$= 49.68$

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[MCQ-2]

Q.13. Match each quantity in column M with the appropriate relation from column N. Here ψ is the Helmholtz function. P is pressure, v is specific volume, T is temperature, h is specific enthalpy and s is specific entropy.

COLUMN M	COLUMN N
(M_1) v	**(N_1)** $-\left.\frac{\partial \psi}{\partial v}\right\|_T$
(M_2) P	**(N_2)** $\left.\frac{\partial \psi}{\partial v}\right\|_T$
(M_3) s	**(N_3)** $\left.\frac{\partial \psi}{\partial T}\right\|_V$
(M_4) T	**(N_4)** $-\left.\frac{\partial \psi}{\partial T}\right\|_V$
	(N_5) $\left.\frac{\partial h}{\partial P}\right\|_s$
	(N_6) $-\left.\frac{\partial h}{\partial s}\right\|_P$
	(N_7) $-\left.\frac{\partial h}{\partial p}\right\|_s$
	(N_8) $\left.\frac{\partial h}{\partial s}\right\|_p$

(a) M_1N_6, M_2N_2, M_3N_3, M_4N_8

(b) M_1N_5, M_2N_1, M_3N_4, M_4N_7

(c) M_1N_5, M_2N_1, M_3N_4, M_4N_8

(d) M_1N_8, M_2N_1, M_3N_4, M_4N_5

Sol. **(c)**

From Tds equation

Tds = dh – vdP

At constant entropy, ds = 0

$$\Rightarrow \left.\frac{dh}{dp}\right|_s = v$$

$\therefore M_1 \rightarrow N_5$

so, option (a) and (d) are eliminated

In option (b) and (c), $M_2 \rightarrow N_1$, $M_3 \rightarrow N_4$

So, checking M_4

From Tds = dh – vdp

$$Tds = dh \Rightarrow \left.\frac{dh}{ds}\right|_p = T$$

$\therefore M4 \rightarrow N8$

So, Option (c) is correct

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[MCQ-2]

Q.14. Equation of state for a non-ideal gas is $\frac{Pv}{RT} = 1 + BP$

Where P is pressure, v is specific volume, R is the specific gas constant, T is temperature and B is a temperature dependent parameter. For this gas the partial derivative of enthalpy with respect to pressure at constant temperature is

(a) $BRT - RT^2\left(\frac{dB}{dT}\right)$ (b) $-RT^2\left(\frac{dB}{dT}\right)$

(c) BRT (d) Zero

Sol. **(d)**

$$dh = c_p dt + \left[v - t\left.\frac{\partial v}{\partial t}\right|_P\right]dp$$

$$\left.\frac{dh}{dp}\right|_{T=C} = \left[v - T\left.\frac{\partial v}{\partial T}\right|_P\right]$$

$$\frac{Pv}{RT} = 1 + BP$$

$$\Rightarrow v = \frac{RT}{P}(1+BP)$$

$$\therefore \left.\frac{\partial v}{\partial T}\right|_P = \frac{R}{P}(1+BP)$$

$$\therefore v - T\left.\frac{\partial v}{\partial T}\right|_P = \frac{RT}{P}(1+BP) - \frac{R}{P}(1+BP).T$$

$= 0$

[NAT-2]

Q.15. An ideal gas undergoes a series of reversible, steady state, steady flow processes between states 1→2→3. Process 1 → 2 satisfies the relation P + 800 v = 900 where pressure P is in kPa and specific volume v is in m^3/kg. Process 2→3 is isochoric and $v_1 = 0.5$ m^3/kg, $v_2 = v_3 = 1$ m^3/kg and $P_3/P_2 = 4$. The total work done per unit mass (in kJ/kg) in the series of processes 1 → 2 → 3 is _____ (round off to nearest integer).

Sol. **(0)**

$P_1 + 800 \times 0.5 = 900$

$P_1 = 500$ kPa

$P_2 + 800 \times 1 = 900$

$P_2 = 100$ kPa

$$\frac{P_3}{P_2} = 4$$

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$\frac{P_3}{100} = 4$

$P_3 = 400$ kPa

$W = W_{1-2} + W_{2-3}$

$\int_1^2 vdp + \int_2^3 vdp$

$\int_1^2 \frac{900-p}{800} + v_2(P_3 - P_2)$

$= \frac{1}{800}\left\{900(P_2 - P_1) - \left[\frac{P_2^2 - P_1^2}{2}\right]\right\} + v_2(P_3 - P_2)$

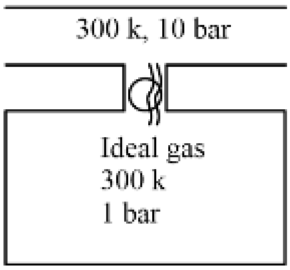
$= \frac{1}{800}\{900(100-500) - [-120000]\} + 1(400-100)$

$= 0$

[NAT-2]

Q.16. A rigid insulated tank containing an ideal gas at 300 K and 1 bar is being filled from an external pressure line supplying the same gas at 300 K and 10 bar, when the mass of gas inside the tank has doubled, its temperature in (K) is (integer nearest) _____. Assume the ratio of specific heats to be constant for the process and equal to 1.4.

Sol. **(360)**



$m_2u_2 - m_1u_1 = (2\text{ m}-\text{m})\ hi$

$2mu_2 - mu_1 = (2\text{ m}-\text{m})\ hi$

$C_v\ (2T_2 - T_1) = C_pT_i$

$2T_2 - T_1 = 1.4\ T_i$

$2T_2 = 1.4 \times 300 + 300$

$T_2 = 360$ K

[MCQ-2]

Q.17. A fixed mass of an ideal gas undergoes two different cycle M and N as shown in the pressure P – volume (v) diagrams. Based on the information provided which one of the following is are true.

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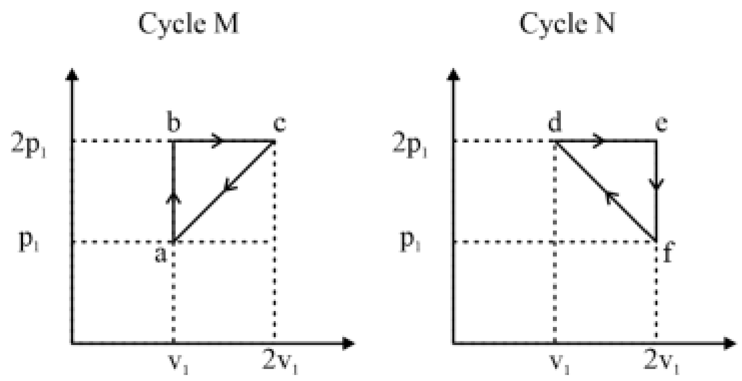


(a) Net heat transfer in cycle M is equal to net heat transfer in cycle N

(b) Heat input in cycle M is equal to heat input in cycle N

(c) Thermal efficiency of cycle M is equal to thermal efficiency of cycle N

(d) Heat rejected in cycle M is equal to that in cycle N

Sol. **(a)**

For a cycle,
Net Heat transfer = Net Work transfer

[NAT-2]

Q.18. The melting point of a substance at 1 bar is 273 K. The following property data is available for this substance at 1 bar
Density of the solid phase = 900 kg/m^3,
Density of liquid phase = 1000 kg/m^3,
Latent heat for melting = 300 kJ/kg.
Assuming that the above properties are constant, the melting point (in K) of the substance at 101 bar is ____(correct up to two decimal places)

Sol. **(271.99)**

$$\left.\frac{dP}{dT}\right|_{sat} = \frac{\Delta H}{T_{sat} = (V_2 - V_1)}$$

$$\Rightarrow \int_{T_{sat_1^1}}^{T_{sat_1^2}} \frac{1}{T_{sat}} dt\Big|_{sat} = \int_{P_1}^{P_2} \frac{V_2 - V_1}{\Delta H} dP\Big|_{sat}$$

$$\Rightarrow \text{In}\left(\frac{T_{sat_1^2}}{T_{sat_1^1}}\right) = \frac{\left(\frac{1}{\rho_l} - \frac{1}{\rho_s}\right)}{\Delta h}(P_2 - P_1)$$

$$\Rightarrow T_{sat_1^2} = T_{sat_1^1} \exp\left\{\frac{\left(\frac{1}{\rho_l} - \frac{1}{\rho_s}\right)(P_2 - P_1)}{\Delta h}\right\}$$

$$\Rightarrow T_{sat_1^2} = 273\exp\left\{\frac{\left(\frac{1}{1000}-\frac{1}{900}\right)(101-1)10^2}{300}\right\}$$

$= 271.99$ kPa

[MCQ-2]

Q.19. A Carnot engine operates between two temperature T_1 and T_2 such that $T_1 > T_2$. If the thermal efficiency of the engine is to be increased by changing one of the temperature by a constant amount $\Delta T > 0$ which one of the following cases will give the highest increase in efficiency.

(a) increasing T_2 by ΔT while keeping T_1 constant

(b) increasing T_1 by ΔT while keeping T_2 constant

(c) decreasing T_1 by ΔT while keeping T_2 constant

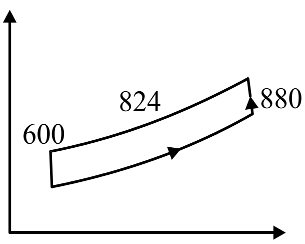
(d) decreasing T_2 by ΔT while keeping T_1 constant

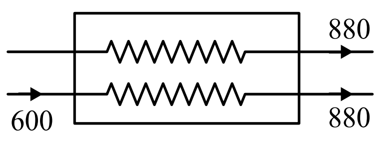
Sol. **(d)**

[NAT-2]

Q.20. Consider the following data from a Brayton cycle
Enthalpy at inlet to turbine = 1400 kJ/kg
Enthalpy at exit to turbine = 880 kJ/kg
Enthalpy at exit to compress = 600 kJ/kg
On adding regenerator of effectiveness equal to 0.8, the absolute value of % change in heat addition is _____ (round off to nearest integer).

Sol. **(28%)**





n = 0.8

$(\text{Heat addel})_1 = 1400 - 600$

$= 800$ kJ/kg

$(\text{Heat added})_2 = 1400 - 824$

$= 576$ kJ/kg

$$\eta = \frac{224}{800} = 28\%$$

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[MCQ-2]

Q.21. 10 kg of water at 300 K is poured into bucket containing 10 kg of water at 350 K. Capacity of water is 4.2 kJ/kg.K. Neglecting any heat losses to the surroundings, the change in the entropy (in kJ/K) of the system during this process ____(round off to two decimal places).

(a) 0.50 (b) 0.25

(c) 0.00 (d) 0.75

Sol. **(b)**

$m_1 = 10$ kg
$m_2 = 10$ kg
$T_1 = 300$ K

$T_2 = 350$ K

Energy balance

$m_1c_w (T_F - T_1) = m_2c_w (T_F - T_1)$

$$T_F = \frac{T_1 + T_2}{2} = 325K$$

$$(ds) = (ds)_1 + (ds)_2$$

$$= mc\left\{\text{In}\frac{T_f}{T_1} + \text{In}\frac{T_f}{T_2}\right\}$$

= 0.25 kJ/k

❑❑❑

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