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GATE 2021

MECHANICAL ENGINEERING

Memory based Questions & Solutions

Exam held on 14/02/2021
Afternoon Session

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GENERAL APTITUDE

Q.1 In a bag there are 15 blue ball and 45 black balls. Two ball are selected randomly without replacement. What is the probability that the first ball is blue and second ball is black.

(a) $\frac{1}{2}$ (b) $\frac{3}{16}$

(c) $\frac{13}{60}$ (d) $\frac{45}{236}$

Ans. (d)

The probability of first ball is blue and second ball is black is given as,

$$P = \frac{15}{60} \times \frac{45}{59} = \frac{45}{236}$$

End of Solution

Q.2 P, Q, R, S, T are five friends to be seated in a row not in the same order. P and T cannot be at the start or end of any row, S cannot be adjacent to P, R should be at second place from the left, how many such combinations are possible?

(a) 2 (b) 3

(c) 5 (d) 4

Ans. (b)

S R P T Q, Q R P T S, S R T P Q

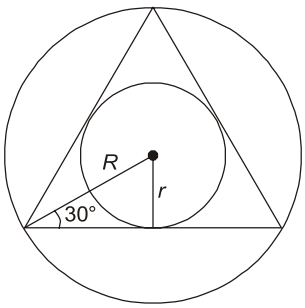
End of Solution

Q.3 There is a circle and inside it there is an inscribed equilateral triangle and then another inscribed circle. Then what is the ratio area of inscribed circle to circumference of circle.

(a) $\frac{1}{2}$ (b) $\frac{1}{4}$

(c) $\frac{1}{3}$ (d) $\frac{1}{8}$

Ans. (b)



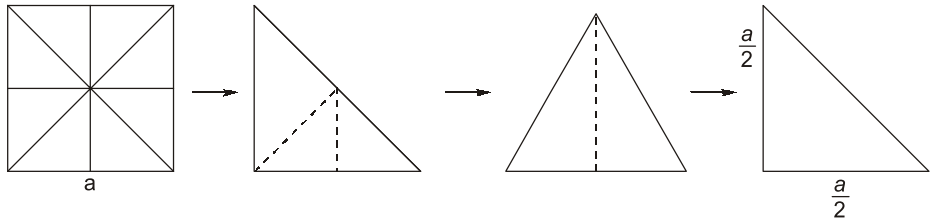
$$\sin 30° = \frac{r}{R}$$

$$\text{Area ratio} = \frac{\pi r^2}{\pi R^2} = \sin^2 30 = \frac{1}{4}$$

End of Solution

Q.4 Square side of limit dimension is folded along the diagonal and then about symmetric axis and then along symmetric axis then find area of resulting plane.

Ans. (#)



$$\text{Area} = \frac{1}{2}, \frac{a}{2}, \frac{a}{2} = \frac{a^2}{8} = \frac{1}{8}$$

End of Solution

Q.5 A digital clock *X* beeps at every 30 sec, another clock *Y* beeps at every 32 second. They beep together at every 32 sec. They beeped together at 10 AM. When will they beep together next?

(a) 10:42 AM (b) 11:00 AM
(c) 10:00 PM (d) 10:08 PM

Ans. (d)

LCM of (30 and 32) is 480

480 seconds = 8 minutes

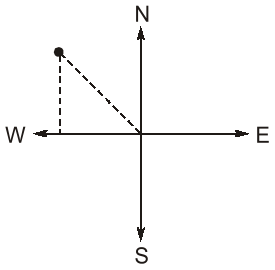
Hence, time will be 10.08 pm

End of Solution

Q.6 The front door of Mr. X's house faces east. He walks 50 m through the back door, which is exactly in the opposite direction of the front gate now he turns right and walks 50 m and thus reaches point *D*. Then direction of point *D* from this starting point is

(a) North (b) West
(c) South-West (d) North-West

Ans. (d)



End of Solution

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MATHEMATICS

Q.7 Consider matrix $R_{n\times 1}$, $X_{1\times n}$ and $Q_{n\times n}$, such that Q is symmetric matrix, the stationary point of $f(x) = \frac{1}{2}X^TQX - R^TX$ is

Ans. **(#)**

Let $Q = \begin{bmatrix} a & c \\ c & b \end{bmatrix}, x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}, R = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$

$$F(x) = \frac{1}{2}(x_1, x_2)\begin{bmatrix} a & c \\ c & b \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} - [r_1\ r_2]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$= \frac{1}{2}\left[ax_1^2 + bx_2^2 + 2cx_1x_2\right] - \left[r_1x_1 + r_2x_2\right]$$

i.e. $$U(x_1, x_2) = \frac{1}{2}ax_1^2 + \frac{1}{2}bx_2^2 + c_1x_1x_2 - r_1x_1 - r_2x_2$$

Now, for critical point, $\frac{\partial u}{\partial x_1} = 0$ and $\frac{\partial u}{\partial x_2} = 0$

$\Rightarrow$ $a_1x_1 + cx_2 - r_1 = 0$ and $cx_2 + cx_1 - r_2 = 0$

In matrix form we can write it as

$$\begin{bmatrix} a & c \\ c & b \end{bmatrix}\begin{bmatrix} x_1 \\ m_2 \end{bmatrix} = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$$

$\Rightarrow$ $Qx = R$

By multiplying both side by Q^{-1}

$$x = Q^{-1}R$$

Q.8 Mean and variance of binomial distribution are?

Ans. **(#)**

Mean $= np$

Variance $= npq = np(1 - p)$

End of Solution

Q.9 Calculate: $\int_0^{\pi/2}\int_0^{\cos\theta} r\sin\theta\, dr d\theta$

(a) 0 (b) π

(c) $\frac{1}{6}$ (d) $\frac{\pi}{6}$

Ans. (#)

$$I = \int_{\theta=0}^{\theta=\frac{\pi}{2}} \int_{r=0}^{r=\cos\theta} r\sin\theta\, dr d\theta$$

$$= \int_{\theta=0}^{\frac{\pi}{2}} \left[\frac{r^2}{2}\right]_0^{\cos\theta} \times \sin\theta d\theta$$

$$= \frac{1}{2}\int_{\theta}^{\frac{\pi}{2}} \sin\theta \cdot \cos^2\theta d\theta = \frac{-1}{2}\left[\frac{\cos^3\theta}{3}\right]_0^{\pi/2}$$

$$= \frac{-1}{2}\left[\frac{-1}{3}\right] = \frac{1}{6}$$

End of Solution

Q.10 $(1+y)\cdot\frac{dy}{dx} = y$ find the condition which satisfy $y(1) = 1$.

(a) $ye^y = e^x$ (b) $ye^y = e^x + e$

(c) $y^2e^y + y = e^x$ (d)

Ans. (#)

$$(1+y)\frac{dy}{dx} = 4$$

$$\Rightarrow \left(\frac{1}{y}+1\right)dy = dx$$

$$\Rightarrow \log y + y = x + c$$

Using, $y(1) = 1$

$$\log 1 + 1 = 1 + c \Rightarrow c = 0$$

Hence, $\log y + y = x$

$$\Rightarrow \log y + y\log e = x$$

$$\log_e(y\cdot e^y) = x$$

$$\Rightarrow ye^y = e^x$$

End of Solution

Q.11 $(1+i)^8$ if $i = \sqrt{-1}$ is _____.

(a) ## (b) ##

(c) ## (d) ##

Ans. (#)

$$(1+i)^8 = [(1+i)^2]^4$$

$$= [1 + i^2 + 2i]^4$$

$$= [2i]^4 = 16$$

End of Solution

Q.12 $f(x) = x^3 - x - 3$ and $x_0 = 2$, find the value of x after 2 iteration using Newton-Raphson method.

Ans. **(#)**

Given, $f(x) = x^3 - x - 3, \quad x_0 = 2$

$f'(x) = 3x^2 - 1$

Iteration 1: $x_1 = x_0 - \dfrac{f(x_0)}{f'(x_0)} = 2 - \dfrac{(8-2-3)}{3(4)-1} = 1.72$

Iteration 2: $x_2 = x_1 - \dfrac{f(x_1)}{f'(x_1)} = 1.72 - \dfrac{(1.72^3 - 1.72 - 3)}{3(1.72)^2 - 1} = 1.67$

End of Solution

Q.13 $L\{f(t)\} = \dfrac{s+3}{(s+1)(s+2)}$ what is the value of $f(0)$?

(a) 0 (b) 1

(c) $\dfrac{1}{2}$ (d) 2

Ans. **(#)**

By using partial fraction concept.

$$f(t) = L^{-1}\left[\frac{s+3}{(s+1)(s+2)}\right]$$

$$= L^{-1}\left[\frac{2}{s+1} - \frac{1}{s+2}\right]$$

$\Rightarrow \quad f(t) = 2e^{-t} - e^{-2t}$

So, $f(c) = 2e^0 - e^0 = 2 - 1 = 1$

End of Solution

Q.14 $\int_4^{5.2} \ln x\, dx$ $h = 0.3$. Evaluate from Simpson $\frac{1}{3}rd$ rule.

Ans. **(#)**

Here $f(x) = \log x$

$a = 4, \quad b = 5.2, \quad h = 0.3$

So, $n = \dfrac{b-a}{h} = \dfrac{5.2-4}{0.3} = 4$

x	4	4.3	4.6	4.9	5.2
y	log4	log4.3	log4.6	log4.9	log5.2
	y_0	y_1	y_2	y_3	y_4

As per Simpson's 1/3rd rule

$$\int_4^{5.2} \log x\,dx = \frac{h}{3}\left[y_0 + y_4 + 4(y_1 + y_3) + 2(y_2)\right]$$

$$= 1.8272$$

End of Solution

Q.15 If $AX = \alpha^2 X$, and A is a $n \times n$ matrix and X is the eigen vector find eigen value of A^2.

(a) α (b) α^2

(c) $\sqrt{\alpha}$ (d) α^4

Ans. **(d)**

Given, $AP = \alpha^2 P$

By comparision with $AX = \lambda X$

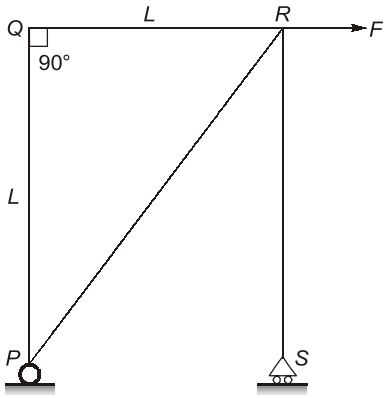
$\Rightarrow$ $\lambda = \alpha^2$

Hence, eigen value of A is α^2, so eigen value of A^2 is α^4.

End of Solution

ENGINEERING MECHANICS

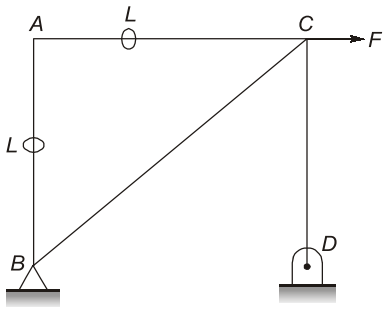
Q.16 Find F_{PR} and F_{RS} along with nature of force?



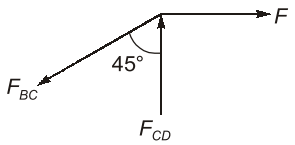
(a) $\sqrt{2}F(T), F(C)$ (b) $\sqrt{2}F(C), F(T)$

(c) F(T), F(C) (d) $\sqrt{2}F(T), \sqrt{2}F(C)$

Ans. (a)



Joint C,



$\Sigma F_H = 0$

$\Rightarrow \quad F_{BC} \sin 45° = F$

$F_{BC} = \sqrt{2}F$ (Tensile)

$\Rightarrow \quad F_{BC} \cos 45° = F_{CD}$

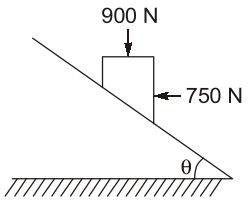
$\Sigma F_V = 0$

$F_{CD} = \cancel{\sqrt{2}}F \times \frac{1}{\cancel{\sqrt{2}}}$

$\Rightarrow \quad F_{CD} = F$ (Comp.)

End of Solution

Q.17 After application of forces block is just about to move (mass is negligible). What is the coefficient of static friction when horizontal force is 750 N and vertical force is 900 N and angle of inclination of plane is 30°.



Ans. (*)

After forces are applied block is just about move (mass is negligible). Calculate coefficient of friction,

$F_H = 750$ N

$F_V = 900$ N

$\theta = 30°$

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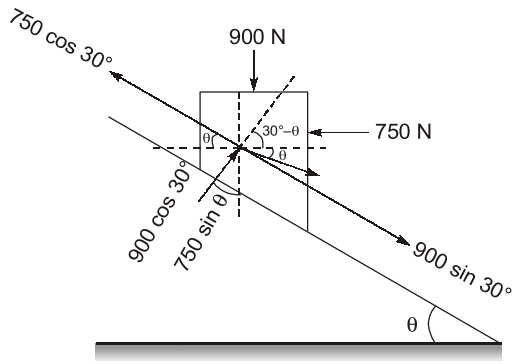
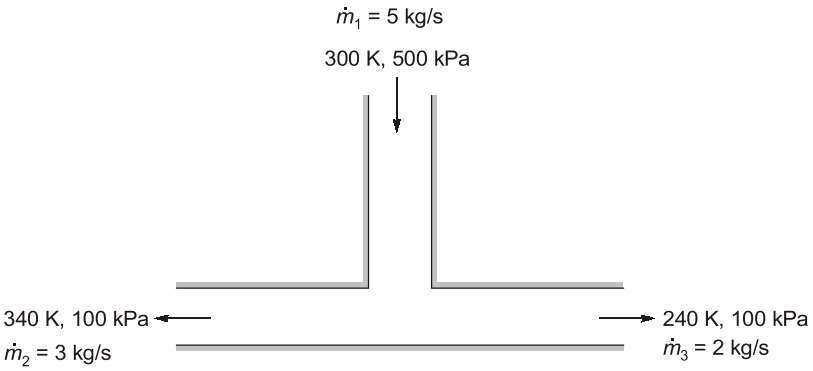


$$N = 900 \cos\theta + 750 \sin\theta$$
$$N = 900 \cos 30° + 750 \sin 30°$$
$$= 1154.4228\ \text{N}$$
$$F_{max} + 900 \sin 30° = 750 \cos 30°$$
$$\mu N = 199.519$$
$$\mu = \frac{199.519}{1154.4228}$$
$$\mu = 0.1728$$

End of Solution

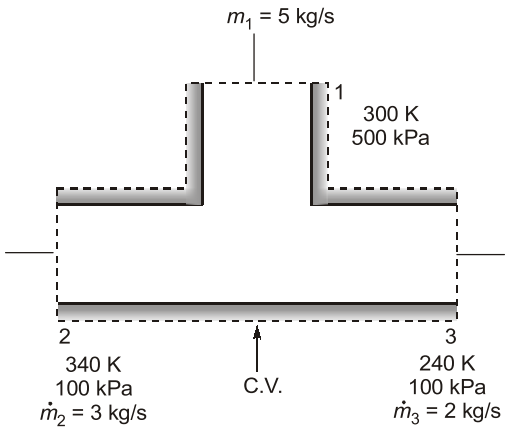
THERMODYNAMICS

Q.18 In a inverse T-tube mass is entering from top and leaving from bottom as shown below.



Find the entropy change?

Ans. (#)



$$\left(\frac{dS}{dt}\right)_{C.V.} = S_i + S_{gen} - S_e$$

$$S_{gen} = S_e - S_i$$

$$= \dot{m}_2 s_2 + \dot{m}_3 s_3 - \dot{m}_1 s_1$$

$$= 3(s_2 - s_1) + 2(s_3 - s_1)$$

$$= 3 \times 0.587 + 2(0.237)$$

$$= 2.235 \text{ kW/K}$$

End of Solution

Q.19 A rigid container contains mixture of liquid and vapour, m_l = 20%, m_v = 80%.
Given : Total volume = 50 m^3
v_f = 0.001048 m^3/kg
v_g = 0.4629 m^3/kg
Find the mass of the mixture.

Ans. (#)

$$V_{total} = v_l + v_v$$

$$= v_f \times m_l + v_g \times m_v$$

$$50 = 0.001048 \times 0.2 \text{ m} + 0.4629 \times 0.8 \text{ m}$$

$$m = 134.9 \text{ kg}$$

End of Solution

POWER PLANT

Q.20 Air having an adiabatic index of 1.4 and characteristic gas constant 287 J/kgK and temperature 323 K flowing with Mach number 0.84. What is the velocity of air?

Ans. (*)

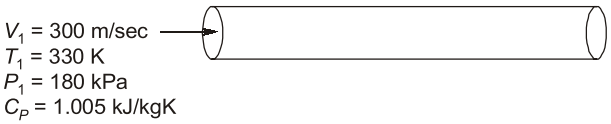
$$M = \frac{V}{C} = \frac{V}{\sqrt{\gamma RT}}$$

$$0.84 = \frac{V}{\sqrt{1.4 \times 287 \times 323}}$$

$$V = 302.6 \text{ m/sec}$$

End of Solution

Q.21 Find the stagnation temperature for the given condition as shown in figure.



(a) ## (b) ##

(c) ## (d) ##

Ans. (#)

$$M_1 = \frac{V_1}{\sqrt{\gamma RT_1}} = \frac{300}{\sqrt{1.4 \times 287 \times 330}} = 0.823$$

$$\frac{T_{o1}}{T_1} = 1 + \frac{\gamma - 1}{2} M_1^2 = 1 + \frac{1.4 - 1}{2}(0.823)^2$$

$$\frac{T_{o1}}{T_1} = 1.154$$

$$T_{01} = 374.7037 \text{ K}$$

End of Solution

RAC

Q.22 COP of a refrigerator is given as 10 and refrigerating effect is 150 kJ/kg then heat transferred from condenser is ____ kJ/kg.

(a) ## (b) ##

(c) ## (d) ##

Ans. (*)

$$\text{RE} = 150 \text{ kJ/kg}$$

$$\text{COP} = 10$$

$$\text{COP} = \frac{RE}{W_{in}}$$

$$\Rightarrow \quad W_{in} = 15 \text{ kJ/kg}$$

$$Q_c = \text{RE} + W_{in}$$

$$= 150 + 15$$

$$= 165 \text{ kJ/kg}$$

End of Solution

Q.23 Consider the following conditions :
Relative humidity = 60%
Total pressure = 101 kPa
and saturation vapour pressure = 3.6 kPa
Find the specific humidity.
(a) ##
(b) ##
(c) ##
(d) ##

Ans. (*)

$$\phi = 0.6$$

$$\frac{P_v}{P_{vs}} = 0.6$$

$$P_{vs} = 3.6 \text{ kPa}$$

$$P_v = 0.6 \times 3.6 \text{ kPa}$$

$$P_v = 2.16 \text{ kPa}$$

$$\omega = 0.622\left(\frac{P_v}{P - P_v}\right)$$

$$= 0.622\left(\frac{2.16}{101 - 2.16}\right)$$

$$= 0.01359 \text{ kg of water vapour/kg of dry air}$$

End of Solution

HMT

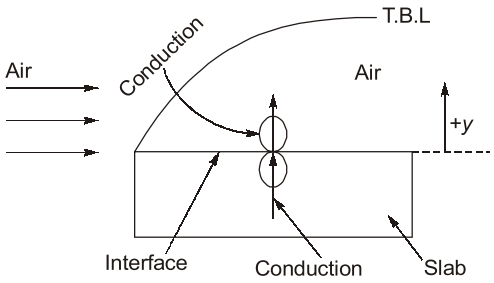
Q.24 Air is flowing on the upper surface of the slab,

Temperature variation of air, $T = 300 + 200e^{-5y}$

$$K_{air} = 1 \text{ W/m-K}$$
$$K_{slab} = 100 \text{ W/m-K}$$

Find temperature gradient in slab at interface.

Ans. (#)



Given that

Temp. variation of air, $T = 300 + 200e^{-5y}$

$K_{air} = 1$ W/m-K

$$K_{slab} = 100 \text{ W/m-K}$$

$$\left.\frac{dT}{dy}\right|_{y=0,\text{ slab}} = ?$$

Applying surface energy balance at interface ($y = 0$)

heat flux leaving from slab at interface by conduction = heat flux received from air at interface by conduction

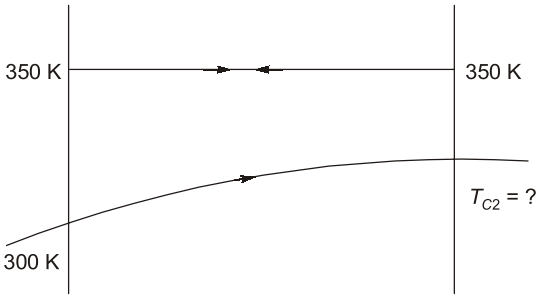
$$-k_{slab}\left.\frac{dT}{dy}\right|_{y=0,slab} = -k_{air}\left.\frac{dT}{dy}\right|_{y=0,\text{ air}}$$

$$\left.\frac{dT}{dy}\right|_{y=0,\text{ air}} = 0 + 200 \times -5 \times 1 = -1000 \text{ K/m}$$

$$-100\left.\frac{dT}{dy}\right|_{y=0,slab} = -1 \times -1000$$

$$\left.\frac{dT}{dy}\right|_{y=0,slab} = -10 \text{ K/m}$$

Q.25 In a parallel flow heat exchanger cold fluid inlet temperature is 300 K and phase change temperature is 350 K. Calculate the cold fluid outlet temperature.



Given :

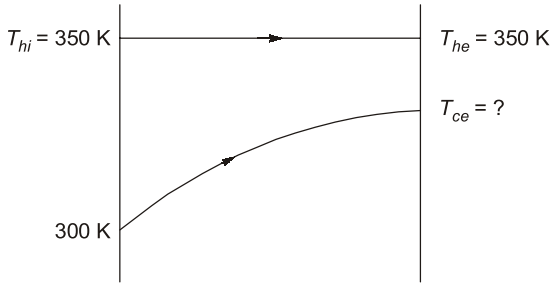
$U = 1500 \text{ W/m}^2\text{K}$

$A = 400 \text{ m}^2$

$\dot{m}_c = 100 \text{ Kg/s}$

$C_P = 4000 \text{ J/kg.K}$

Ans. (#)



$$NTU = \frac{UA}{(\dot{m}c_p)_{small}} = \frac{1500 \times 400}{100 \times 4000} = 1.5$$

$$\epsilon_{HE} = 1 - e^{-NTU} = \frac{T_{ce} - T_{ci}}{T_{hi} - T_{ci}} = \frac{T_{ce} - 300}{350 - 300} = 0.7768$$

$$T_{ce} = 338.84 \text{ K}$$

End of Solution

Q.26 What is the correct relation of Stanton number?

Ans. (#)

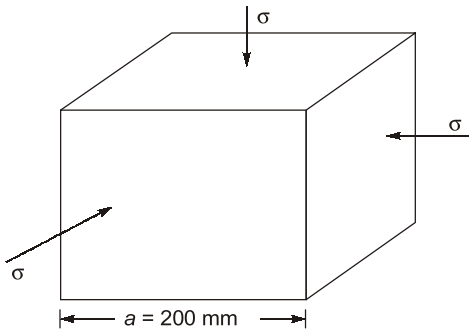
$$St = \frac{Nu}{Re \times Pr}$$

End of Solution

SOM

Q.27 A cube of side 200 mm is subjected under hydrostatic pressure 420 N/mm^2, given $\mu = 0.3$, $E = 200 \times 10^4$ N/mm^2. Find reducing edge of cube.

Ans. (#)



$E = 200$ GPa

$\sigma = 400$ MPa

$\mu = 0.3$

$$\epsilon_x = \epsilon_y = \epsilon_z = \frac{\delta a}{a}$$

$$\frac{1}{E}\left[\sigma_x - \mu(\sigma_y + \sigma_z)\right] = \frac{(\delta a)}{a}$$

$$\left(\frac{-\sigma}{E}\right)(1 - 2\mu) = \frac{\delta a}{a}$$

$$\delta a = -\frac{(400)(1 - 0.6)(200)}{200 \times 10^3}$$

$$\delta a = (-)\ 0.16 \text{ mm}$$

Reduction in side of cube is 0.16 mm.

End of Solution

Q.28 Von Mises stress is proportional to square root of which energy

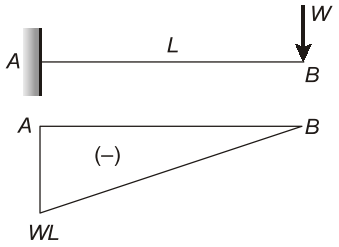
(a) Strain Energy
(b) Distortional Strain Energy
(c) Total Strain Energy
(d) Dilational Strain Energy

Ans. (b)

End of Solution

Q.29 For a cantilever beam subjected to point load the area of BM diagram is 10000 Nm^2 if $EI = 200 \times 10^6$; then slope at free end in micro radians is

Neglect σ_{axial} ε_1, $\sigma_{transverse\ shear}$

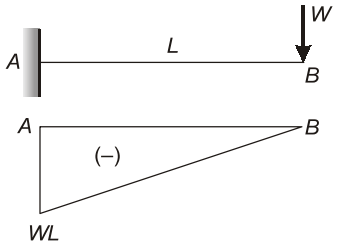


Ans. (#)

Assume:

A =10000 N-m^2

EI = 200×10^6 N-m^2



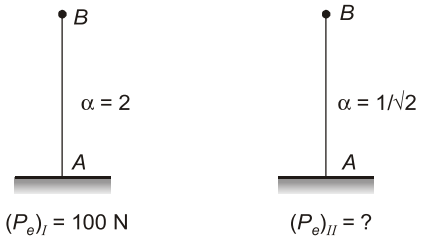
$$\theta_B - \theta_A = \left(\frac{A}{EI}\right)AB$$

$$\theta_B - 0 = \frac{10000}{200\times10^6} = 0.5 \times 10^{-4} \text{ radians}$$

$$\theta_B = 50\ \mu \text{ radians}$$

Q.30 A column is fixed at one end and other end is free. Free end is subjected with a critical buckling load of 100 N. If free end is to be hinged, then find out the new critical load for buckling?

Ans. (#)



$(P_e)_I = 100$ N $\qquad (P_e)_{II} = ?$

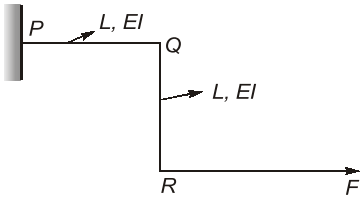
$$\frac{(Pe)_{II}}{(Pe)_I} = \left(\frac{L_I}{L_{II}}\right)^2 = \left(\frac{2L}{1/\sqrt{2}}\right)^2 = 8$$

$$(P_e)_{II} = 8(P_e)_I = 800 \text{ N}$$

End of Solution

Q.31 For the given frame as shown in the figure, find the horizontal deflection of point R, neglecting axial effect of force and transverse effect of force.

Ans. (#)



$$U = U_{PQ} + U_{QP}$$

$$U = \frac{M^2 L}{2EI} + \int_0^L \frac{(M_{x-x})^2 (dx)}{2EI}$$

$$U = \frac{(FL)^2 L}{2EI} + \int_0^L \left(\frac{(Fx)^2 (dx)}{2EI}\right)$$

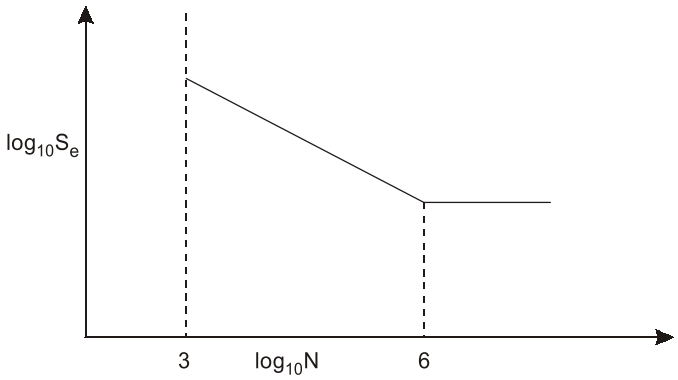
$$U = \frac{F^2 L^3}{2EI} + \frac{F^2 L^3}{6EI} = \frac{2F^2 L^3}{3EI}$$

$$(\delta_H)_R = \frac{\partial U}{\partial F} = \frac{4FL^3}{3EI}$$

End of Solution

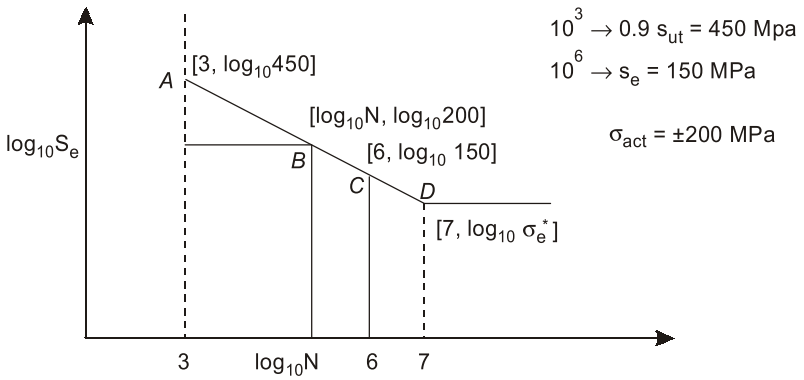
MACHINE DESIGN

Q.32 The fatigue curve for the element on a log –log plot is shown below. The number of cycle for a operating stress of 200 MPa.



$10^3 \rightarrow 0.9\ s_{ut} = 450$ MPa
$10^6 \rightarrow s_e \rightarrow 150$ MPa
N for $\sigma_a = 200$ MPa

Ans. (#)



A - B

$$y - y_1 = \frac{(y_2 - y_1)}{(x_2 - x_1)}[x - x_1]$$

$$\log_{10}200 - \log_{10}450 = \frac{\log_{10}150 - \log_{10}450}{(6-3)}[\log_{10}N - 3]$$

$$N = 163840.580 \text{ cycles}$$

You can also find out endurance limit

Slope of AC = Slope of CD

$$\frac{\log_{10}150-\log_{10}450}{(6-3)}=\frac{\log_{10}\sigma_e^*-\log_{10}150}{7-6}$$

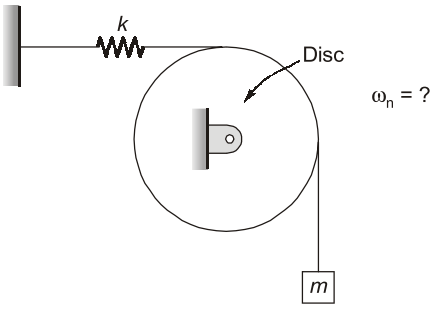
Endurance limit

$$\sigma_e^* = 104.004 \text{ MPa}$$

End of Solution

THEORY OF MACHINES

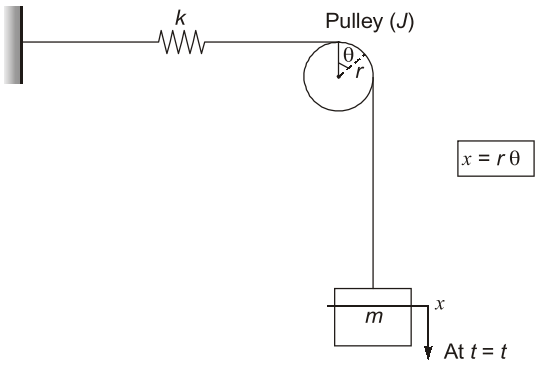
Q.33 If J is the moment of inertia of Disc and 'r' is the radius. Find the natural frequency



(a) $\sqrt{\frac{kr^2}{J+mr^2}}$ (b) $\sqrt{\frac{k}{J-mr^2}}$

(c) $\sqrt{\frac{k}{m}}$ (d) $\sqrt{\frac{k}{J}}$

Ans. (a)



$$E=\frac{1}{2}m\dot{x}^2+\frac{1}{2}kx^2+\frac{1}{2}I\omega^2$$
$$=\frac{1}{2}mr^2\dot{\theta}^2+\frac{1}{2}kr^2\theta^2+\frac{1}{2}J\dot{\theta}^2$$
$$=\frac{1}{2}\left[\left(J+mr^2\right)\dot{\theta}^2+kr^2\theta^2\right]=0$$

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

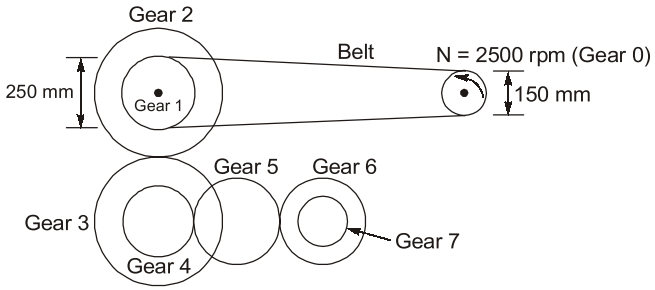
$$\left(J + mr^2\right) \times 2\dot{\theta}\ddot{\theta} + kr^2 2\theta\dot{\theta} = 0$$

$$\left(\ddot{\theta} + \frac{kr^2}{J + mr^2}\right)\theta = 0$$

$$\omega_n = \sqrt{\frac{kr^2}{J + mr^2}}$$

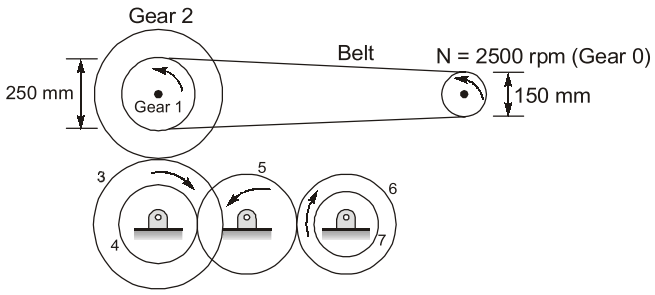
End of Solution

Q.34 What is the speed and direction of gear 7?



Given: $T_3 = 44;\ T_6 = 36;\ T_2 = 18;\ T_4 = 15$

Ans. ()



$$T_3 = 44$$
$$T_6 = 36$$
$$T_2 = 18$$
$$T_4 = 15$$

$$\frac{N_1}{N_0} = \frac{d_0}{d_1}$$

$$\Rightarrow \quad N_1 = \frac{150}{25} \times 2500$$

$$N_1 = 15{,}000 = N_2$$

$$N_3 = \frac{N_2 \times T_2}{T_3} = \frac{15000 \times 18}{44} = 6136.3636 = N_4$$

$$N_6 = \frac{N_4 \times T_4}{T_6} = \frac{6136.3636 \times 15}{36} = 2556.818 = N_7 \text{ (Clockwise)}$$

Gear 5 is idler

End of Solution

Q.35 Force frequency = 40 rad/s, m = 100 kg. An isolator is provided having stiffness and damper. Arrange the transmitted force in ascending order

1. k = 64 kN/m; ξ = 0.7
2. k = 64 kN/m; ξ = 0.07
3. k = 22.5 kN/m; ξ = 0.7
2. k = 22.5 kN/m; ξ = 0.07

(a) 4 - 3 - 1 - 2 (b) 4 - 2 - 1 - 3

(c) ## (d) ##

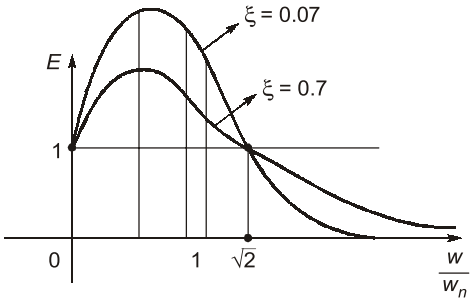
Ans. **(#)**

Transmitted force problem:

ω = 40 rad/s (force frequency)

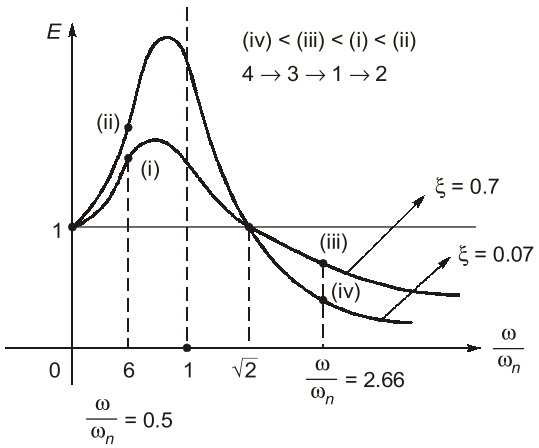
m = 100 kg

$$\epsilon = \frac{\sqrt{1+\left\{\frac{2\xi\omega}{\omega_n}\right\}^2}}{\sqrt{\left\{1-\left(\frac{\omega}{\omega_n}\right)^2+\left\{\frac{2\xi\omega}{\omega_n}\right\}^2\right\}}}$$



$$\omega_n = \sqrt{\frac{640\times10^3}{100}} = 80 \Rightarrow \frac{\omega}{\omega_n} = 0.5$$

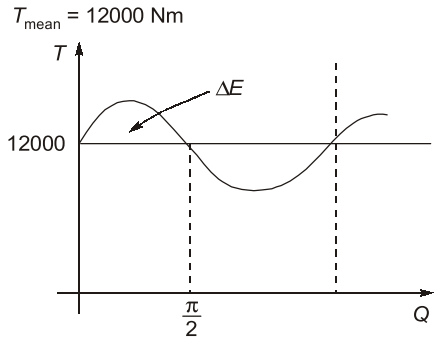
$$\omega_n = \sqrt{\frac{22.5\times10^3}{100}} = 47.434164 \Rightarrow \frac{\omega}{\omega_n} = \frac{40}{15} = 2.666$$



End of Solution

Q.36 $T = 12000 + 2500 \sin 2\theta$, $C_s = \pm 0.5\%$, $N = 200$ rpm; $I = ?$

Ans. (#)



$$\omega = \frac{\pi \times 200}{30} = 20.9439 \text{ rad/s}$$

$$\Delta E = \int_0^{\frac{\pi}{2}} (T - T_{mean})\, d\theta = 2500 \int_0^{\frac{\pi}{2}} \sin 2\theta\, d\theta$$

$$= 2500 \times 1 = 2500 \text{ J}$$

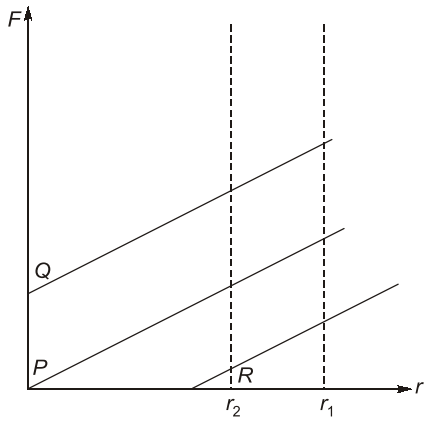
$$\Delta E = I\omega^2 C_s$$

$$2500 = I \times 20.9439^2 \times 0.01$$

$$\Rightarrow \quad I = 569.934 \text{ kgm}^2$$

End of Solution

Q.37 Which of the below option is correct for the given figure of governor?

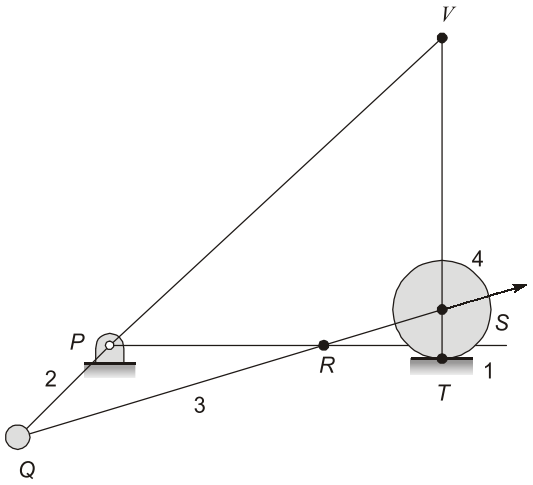


(a) P = isochronous, R = stable, Q = unstable
(b) P = stable, R = isochronous, Q = unstable
(c) P = unstable, R = stable, Q = isochronous
(d) P = isochronous, R = unstable, Q = stable

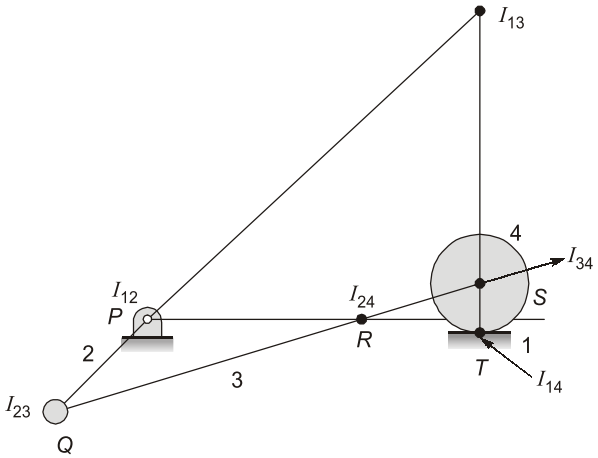
Ans. (a)

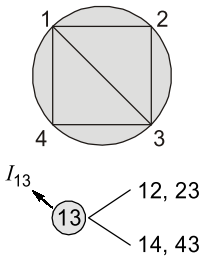
End of Solution

Q.38 For the given mechanism as shown in the figure, what will be the instantaneous center of rotation at point V.



Ans. ()





End of Solution

PRODUCTION

Q.39 Orthogonal cutting rake angle = 0°.

F_s = 400 N
V = 100 m/min
V_C = 50 m/min
d = 3 mm
f = 0.1 mm/rev

Find shear stress.

Ans. (#)

Rake angle = 0°
F_s = 400 N
V = 100 m/min
V_C = 50 m/min
d = 3 mm
f = 0.1 mm/rev

$$\tau_s = F_s \times A$$

$$= 400 \times \frac{wt}{\sin\phi}$$

$$r = \frac{t}{t_c} = \frac{V_c}{V} = \frac{\sin\phi}{\cos(\phi-\alpha)}$$

$$r = \frac{50}{100} = 0.5$$

$$\tan\phi = \frac{r\cos\theta}{1-r\sin\theta} = r = 0.5$$

$$\phi = 26.56$$

$$\tau_s = F_s \times A$$

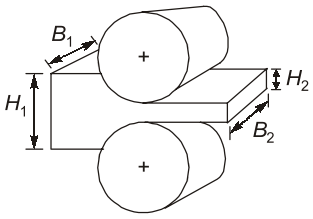
$$= 400 \times \frac{0.1\times 3}{\sin 26.56} = 268.37 \text{MPa}$$

End of Solution

Q.40 In rolling operation N = 3600 rpm; l = 250 mm; b = 300 mm; H_1 = 50 mm. Thickness is reduced by 10%, width is increased by 3% then what is the final length of rolled part?

Ans. (#)

Given : N = 3600 rpm; l = 250 mm; b = 300 mm; H_1 = 50 mm



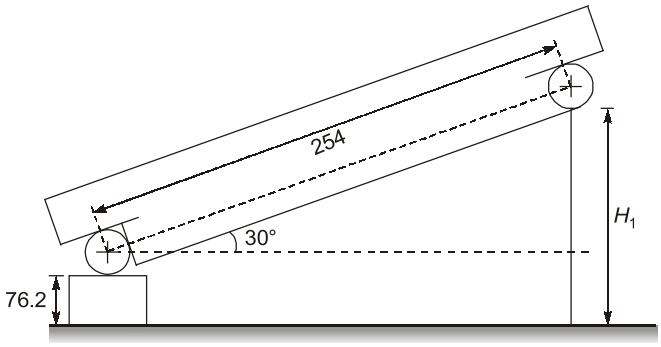
$$H_1B_1L_1 = H_2B_2L_2$$
$$H_1 \times B_1L_1 = 0.9H_1 \times 1.03B_1 \times L_2$$
$$L_1 = 0.9 \times 1.03L_2$$
$$L_2 = 269.68 \text{ mm}$$

End of Solution

Q.41 Height of guage on one side of sine bar is 76.2 mm having length of 254 mm, diameter of roller is 25.4 mm and it is to measure an angle of 30°. Then the guage length which should be placed on other roller is _____ mm.

Ans. (*)

Sine bar



$$\sin 30° = \frac{H_1 - 76.2}{254}$$
$$254 \sin 30° + 76.2 = H_1$$
$$H_1 = 203.2 \text{ mm}$$

End of Solution

Q.42 Allowance is the difference between

(a) upper limit of hole and lower limit of shaft
(b) lower limit of hole and upper limit of shaft
(c) lower limit of hole and lower limit of shaft
(d) upper limit of and upper limit of shaft

Ans. (b)

End of Solution

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Q.43 In powder metallurgy size distribution is measured by

(a) Laser Scattering (b) Laser Absorption

(c) Laser Reflection (d) ##

Ans. (a)

End of Solution

Q.44 Solidification time of casting of cuboid of dimension 250 mm × 50 mm × 100 mm is 8 minutes. What is the solidification time of cylindrical casting of ($h = D = 50$ mm)

Ans. (*)

Solidificaiton time of casting of cuboid of dimension $250 \times 100 \times 50\ mm^3$ is 8 minutes. Find solidification time of cylindrical casting ($h = d = 50$ mm)

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

$$\frac{(t_s)_{cu}}{(t_s)_{cy}} = \frac{\left(\frac{V}{A}\right)^2_{cu}}{\left(\frac{V}{A}\right)^2_{cy}}$$

$$\left(\frac{V}{A}\right)_{cy} = \frac{\frac{\pi}{4}d^2h}{2\frac{\pi}{4}d^2 + \pi dh}$$

Given, $h = d$

$$= \frac{\frac{\pi d^3}{4}}{\frac{3\pi d^2}{2}} = \frac{d}{6} = \frac{\left(\frac{250\times100\times50}{2(250\times100+100\times50+50\times250)}\right)^2}{\left(\frac{50}{6}\right)^2} = 3.114$$

$$= \frac{8}{(t_s)_{cy}} = 3.114$$

$$(t_s)_{cy} = \frac{8}{3.114} = 2.569$$

$$(t_s)_{cy} = 2.569 \text{ minutes}$$

End of Solution

Q.45 Weld nuggets with $D = 5$ mm, $t = 1$ mm, is formed and current is passed for 0.1 second. Heat required for melting is $20\ J/mm^3$. If only 10% input energy is converted into heat. What is the power required for welding in kW.

Ans. (*)

Heat transfer efficiency = 10%

Energy required to melt = 20 J/mm^3

Diameter of nugget = 5 mm

Thickness = 1 mm

Time = 0.1 second

$$\text{Heat required to melt, } Q = 20 \text{ J/mm}^3 \times \frac{\pi}{4}(5)^2 \times 1 = 392.5 \text{ J}$$

$$\text{Power} = \frac{\text{Heat required to melt}}{\text{Time}}$$

$$P = \frac{392.5}{0.1} \text{J/s}$$

$$P = 3925 \text{ J/s} = 3925 \text{ W}$$

$$\text{Actual power supplied} = \frac{3925}{\eta_{th}}$$

$$\eta_{th} = 10\%$$

$$P = \frac{3925}{0.1} = 39250 \text{ W} = 39.25 \text{ kW}$$

End of Solution

Q.46 True strain for 60% height reduction of a sample subjected to hot forging is ____

Ans. (#)

True strain for 60% height reduction of a sample subjected to hot forging is

$$\epsilon_T = \ln\frac{h_f}{h_i}$$

$$\epsilon_T = \ln\frac{0.4h_i}{h_i}$$

$$= -0.916$$

End of Solution

Q.47 Which unconventional machining involves abation?

(a) ECM (b) Chemical machining

(c) Laser beam machining (d) Ultrasonic machining

Ans. (c)

End of Solution

MATERIAL SCIENCE

Q.48 Which cast iron contains only cementite?

(a) Malleable Cast Iron (b) Grey Cast Iron
(c) White Cast Iron (d) Spherodise Cast Iron

Ans. (c)

End of Solution

Q.49 Which one of the following is the correct decreasing order of quenching power for steel head treatment?

(a) Brine, Water, Oil, Air (b) Water, Oil, Brine, Air
(c) Oil, Brine, Water, Air (d) ##

Ans. (a)

End of Solution

FLUID MECHANICS

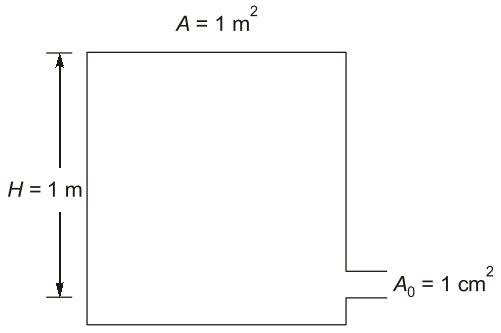
Q.50 Eddy viscosity (Turbulent viscosity) comes due to

(a) Reynolds stresses (b) Prandtl stresses
(c) Boussineq stresses (d) Nikuradse stresses

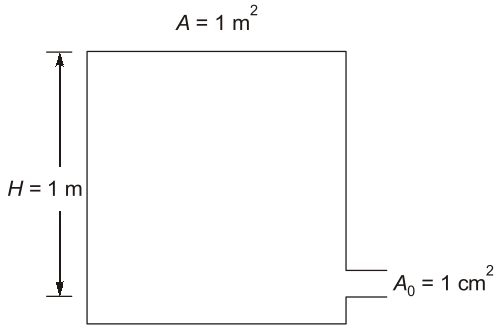
Ans. (c)

End of Solution

Q.51 Tank is filled with water having area of A, and having an orifice at the bottom, having area in A_0, then find the time required for the liquid level to reach $\left(\frac{H}{4}\right)$?



Ans. (#)



$$\dot{m}_{in} - \dot{m}_{out} = \frac{dm_w}{dt}$$

$$-\rho A_o\sqrt{2gH} = \frac{d}{dt}[A \times H \times \rho]$$

$$dt = -\frac{A}{A_o} \times \frac{1}{\sqrt{2g}} \times \frac{dH}{\sqrt{H}}$$

$$t = -\frac{A}{A_o} \times \frac{1}{\sqrt{2g}} \int_1^{0.25} \frac{dH}{\sqrt{H}}$$

$$t = \frac{A}{A_o} \times \frac{1}{\sqrt{2g}} (2\sqrt{H})_{0.25}^{1}$$

$$t = \frac{1}{10^{-4}}\left(1 - \frac{1}{2}\right) \times \frac{1}{\sqrt{2 \times 9.81}}$$

$$= 37.62 \text{ min}$$

$$t = 2257.6 \text{ sec}$$

Q.52 $u = 2xyt,\ v = -y^2t$

Find the equation of stream line at point (1, 1) equation of stream line in 2D.

Ans. (*)

$$u = 2xyt$$

$$v = -y^2t$$

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$$

$$\frac{dx}{2xyt} = \frac{dy}{-y^2t}$$

$$-ydx = 2xdy$$

$$\ln xy^2 = C$$

$$xy^2 = 1$$

End of Solution

Q.53 For 2D-incompressible flow, value of $\frac{\partial}{\partial x}(u^2)+\frac{\partial}{\partial y}(uv)=?$

(a) $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}$

(b) $u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}$

(c) $u\frac{\partial u}{\partial y}+v\frac{\partial v}{\partial x}$

(d) $u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}$

Ans. (d)

Continuity equation $\frac{\partial(u^2)}{\partial x}+\frac{\partial(uv)}{\partial y}$

Incompressible flow $2u\left[\frac{\partial u}{\partial x}\right]+u\frac{\partial v}{\partial y}+v\frac{\partial u}{\partial y}$

$u\frac{\partial u}{\partial x}+\left[u\frac{\partial u}{\partial x}+u\frac{\partial v}{\partial y}\right]+v\frac{\partial u}{\partial y}$

$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}$

End of Solution

INDUSTRIAL ENGINEERING

Q.54 What is MAPE (in %)?

Month	Demand	Forecast
April	225	200
May	220	240
June	285	300
July	290	270
August	250	230

Ans. (#)

March	Di	Fi	ei	$\left\|\frac{ei}{Di}\times 100\right\|$
April	225	200	25	11.11%
May	220	240	-20	9.09%
June	285	300	-15	5.26%
July	290	270	20	6.896%
August	250	230	20	8.0%
				$\sum\left\|\frac{ei}{Di}\times 100\right\| = 40.356$

$$\text{MAPE} = \frac{\sum\left|\frac{ei}{Di}\times 100\right|}{n} = 8.0712\%$$

End of Solution

Q.55 In a CPM network, 9 activities are critical each having standard deviation of 3. What is the standard deviation of critical path?

(a) 9 (b) 27

(c) 81 (d) 18

Ans. **(a)**

In CPM,

$$\sigma = \sqrt{\text{sum of variance along critical path}}$$

$$\sigma = \sqrt{\sigma^2+\sigma^2+.....+\sigma^2}$$

$$\sigma = \sqrt{9\sigma^2} = \sqrt{9\times 9} = 9$$

End of Solutionn

Q.56 In a production model, for the following data. Calculate the economic order quantity

p = 30,000/day

d = 15000/day

C_h = ₹ 20 unit/year

C_o = ₹ 1800

Number of days in a year = 300

Ans. **(#)**

$$Q^* = \sqrt{\frac{2D\times C_0}{C_h}\times\frac{P}{P-d}}$$

$$= \sqrt{\frac{2\times 15000\times 300\times 1800}{20}\times\left(\frac{30}{30-15}\right)}$$

$$= 40249.2 \simeq 40250 \text{ units}$$

End of Solution