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GATE – 2019
Questions with Detailed Solutions

MECHANICAL ENGINEERING

Afternoon Session

All Queries related to **GATE- 2019** Solutions are to be sent to the following email address
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GENERAL APTITUDE

01. Are there enough seats here? There are _______ people here than I expected.

(A) more (B) least

(C) many (D) most

01. Ans: (A)

Sol: The sentence is in comparative degree ‘more… than’.

End of Solution

02. A final examination is the _____ of a series of evaluations that a student has to go through.

(A) consultation (B) culmination

(C) desperation (D) insinuation

02. Ans: (B)

Sol: Culmination means the end or final result of something.

End of Solution

03. If IMHO = JNIP; IDK =JEL: and SO =TP, then IDC = ____.

(A) JDC (B) JCD

(C) JDE (D) JED

03. Ans: (D)

Sol: The given words are coded as follows

$I \xrightarrow{+1} J$, $M \xrightarrow{+1} N$, $H \xrightarrow{+1} I$, $O \xrightarrow{+1} P$

$I \xrightarrow{+1} J$, $D \xrightarrow{+1} E$, $K \xrightarrow{+1} L$

$S \xrightarrow{+1} T$, $O \xrightarrow{+1} P$

Then

$I \xrightarrow{+1} J$, $D \xrightarrow{+1} E$, $C \xrightarrow{+1} D$

∴ Option (D) is correct

04. The product of three integers X, Y and Z is 192. Z is equal to 4 and P is equal to the average of X and Y. What is the minimum possible value of P?

(A) 9.5 (B) 6

(C) 8 (D) 7

04. Ans: (D)

Sol: The product of three integers = X,Y and Z = 192

XYZ = 192, Z = 4

$P = \frac{X+Y}{2}$, P_{min} = ?

XYZ = 192

$XY = \frac{192}{4} = 48$

The product of X,Y = 48, as follows

(1, 48), (2, 24), (3,16), (4, 12) and (6, 8)

$$P = \left(\frac{X+Y}{2}\right)$$

$$P = \frac{1+48}{2} = 24.5$$

$$P = \frac{2+24}{2} = 13$$

$$P = \frac{3+16}{2} = 9.5$$

$$P = \frac{4+12}{2} = 8$$

$$P = \frac{6+8}{2} = 7$$

$\therefore P_{min}$ = '7'

Hence, option (D) is correct

05. Once the team of analysis identify the problem, we ______ in a better position to comment on the issue.

Which one of the following choices CANNOT fill the given blank?

(A) were to be (B) might be

(C) are going to be (D) will be

05. Ans: (A)

Sol: Options B, C and D indicate future and are possible to fill in the blank whereas the given question states (which one of the following choices CANNOT fill the given blank) therefore, option (A) cannot be filled in the given blank.

End of Solution

06. Mola is a digital platform for taxis in a city. It offers three types of rides- Pool, Mini and Prime. The table below presents the number of rides for the past four months. The platform earns one US dollar per ride. What is the percentage share of revenue contributed by Prime to the total revenues of Mola, for the entire duration?

Type	**Month**			
	January	**February**	**March**	**April**
Pool	170	320	215	190
Mini	110	220	180	70
Prime	75	180	120	90

(A) 38.74 (B) 25.86

(C) 23.97 (D) 16.24

06. Ans: (C)

Sol: Total Revenues of Mola from all types of Rides

= 170 + 320 + 215 + 190(pool) + 110 + 220 + 180 + 70(Mini) + 75 + 180 + 120 + 90(prime)

=1940

Revenue contribute by prime ride = 75 + 180 + 120 + 90 = 465

∴ The percentage of share of revenue contributed by prime to the total revenue of Mola

$$= \frac{465}{1940} \times 100$$

$$= 23.97$$

Hence, option (C) is correct.

End of Solution

07. Fiscal deficit was 4% of the GDP in 2015 and that increased to 5% in 2016. If the GDP increased by 10% from 2015 to 2016, the percentage increase in the actual fiscal deficit is___

(A) 37.50 (B) 25.00

(C) 35.70 (D) 10.00

07. Ans: (A)

Sol: Fiscal deficit (F.D) in 2015 = 4 % of GDP

Fiscal deficit (F.D) in 2016 = 5 % of GDP

GDP in 2016 = 10% ↑ of GDP in 2015

$GDP_{2016} = 1.1\ GDP_{2015}$

Assume $GDP_{2015} = x$

$GDP_{2016} = 1.1\ x$

$$F.D_{2015} = \frac{4}{100} \times x = \frac{4x}{100}$$

$$F.D_{2016} = \frac{5}{100} \times 1.1x = \frac{5.5x}{100}$$

$$\text{Actual Increase F.D} = \frac{F.D_{2016} - F.D_{2015}}{F.D_{2015}} \times 100$$

$$= \frac{\frac{5.5x}{100} - \frac{4x}{100}}{\frac{4x}{100}} \times 100 = \frac{1.5x}{4x} \times 100 = 37.50\%$$

∴ Hence, option (A) is correct

08. While teaching a creative writing class in India, I was surprised at receiving stories from the students that were all set in distant places: in the American West with cowboys and in Manhattan penthouses with clinking ice cubes. This was, till an eminent Caribbean writer gave the writers in the once-colonised countries the confidence to see the shabby lives around them as worthy of being "told"

The writer of this passage is surprised by the creative writing assignments of his students, because______.

(A) Some of the students had written about ice cubes and cowboys

(B) None of the students had written about ice cubes and cowboys

(C) Some of the students had written stories set in foreign places

(D) None of the students had written stories set in India

08. Ans: (D)

Sol: No where the word 'some' is mentioned. So, 'D' is the right statement.

End of Solution

09. Two pipes P and Q can fill a tank in 6 hours and 9 hours respectively, while a third pipe R can empty the tank in 12 hours. Initially, P and R are open for 4 hours. Then P is closed and Q is opened. After 6 more hours R is closed. The total time taken to fill the tank (in hours) is__

(A) 14.50 (B) 16.50 (C) 15.50 (D) 13.50

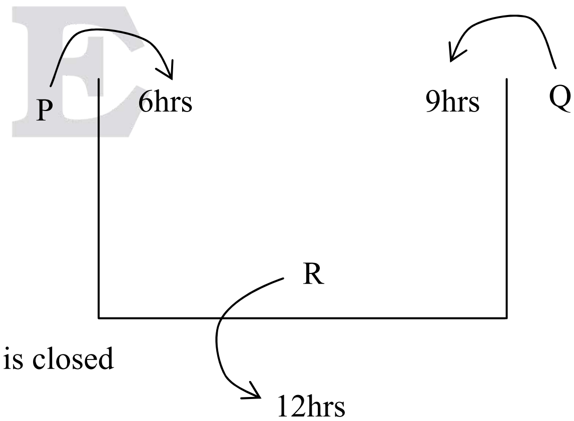
09. Ans: (A)

Sol: P can fill in 1 hr = $\frac{1}{6}$ th part (+ve)

Q can fill in 1 hr = $\frac{1}{9}$ th part (+ve)

R can empty in 1 hr = $\frac{1}{12}$ th part (–ve)

P and R can fill in 4 hr = $4\left[\frac{1}{6}-\frac{1}{12}\right]=\frac{1}{3}$ th part then P is closed



For 6 more hours Q and R can fill = $4\left[\frac{1}{9}-\frac{1}{12}\right]=\frac{1}{6}$th part

Tank fill in 4 + 6 = 10 hrs = $\frac{1}{3}+\frac{1}{6}=\frac{1}{2}$th part

The remaining half of the tank can fill by Q only in = $\frac{1}{2}\times 9=4.5hrs$

$\therefore$ The total time taken to fill the tank = 10 + 4.5 = 14.5 hrs

$\therefore$ Hence, option (A) is correct.

End of Solution

10. X is an online provider. By offering unlimited and exclusive online content at attractive prices for a loyalty membership, X is almost forcing its customers towards its loyalty membership. If its loyalty membership continues to grow at its current rate, within the next eight years more households will be watching X than cable television.

Which one of the following statements can be inferred from the above paragraph?

(A) Non-members prefer to watch cable television

(B) The X is cancelling accounts of non-members

(C) Most households that subscribe to X's loyalty membership discontinue watching cable television

(D) Cable television operators don't subscribe to X's loyalty membership

10. Ans: (C)

Sol: The last sentence of the paragraph states house holds will be watching X than cable television.

MECHANICAL ENGINEERING

01. One –dimensional steady state heat conduction takes place through a solid whose cross-sectional area varies linearly in the direction of heat transfer. Assume there is no heat generation in the solid and the thermal conductivity of the material is constant and independent of temperature. The temperature distribution in the solid is

(A) Linear (B) Logarithmic

(C) Quadratic (D) Exponential

01. Ans: (B)

Sol: Area (A) $\propto$ x

$A = cx$

According to Fourier's law of heat conduction

$$Q = -kA\frac{dT}{dx}$$

$$Q = -k.cx\frac{dT}{dx}$$

$$Q\frac{dx}{x} = -kc\,dT$$

$$\int dT = -\frac{Q}{kc}\int\frac{dx}{x}$$

$$T = -\frac{Q}{kc}\ln x + c_1$$

Temperature distribution is logarithmic.

(or)

In hollow cylinder, area is linearly proportional to radius.

$A = 2\pi r L$

Temperature profile is logarithmic in case of hollow cylinder with no heat generation.

02. Sphere 1 with a diameter of 0.1 m is completely enclosed by another sphere 2 of diameter 0.4 m. The view factor F_{12} is

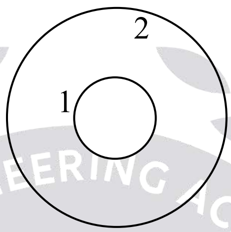
(A) 1.0 (B) 0.0625

(C) 0.25 (D) 0.5

02. Ans: (A)

Sol:

Given data:



$d_1 = 0.1$ m

$d_2 = 0.4$ m

$F_{1\text{-}1} = 0$ (from the geometry)

From the additive rule

$F_{1\text{-}1} + F_{1\text{-}2} = 1$

$F_{1\text{-}2} = 1$

End of Solution

03. The directional derivative of the function $f(x, y) = x^2 + y^2$ along a line directed from (0,0) to (1,1), evaluated at the point x = 1, y = 1 is

(A) $2\sqrt{2}$ (B) 2

(C) $4\sqrt{2}$ (D) $\sqrt{2}$

03. Ans: (A)

Sol: Given function is $f(x, y) = x^2 + y^2$

The direction vector $\bar{a}$ is given by

$$\bar{a} = (1, 1) - (0, 0) = \bar{i} + \bar{j}$$

Let the given point be P=(x, y) = (1, 1)

Now, the directional directive of f(x, y) in the direction of vector $\bar{a}$ at point is given by

$$D.D = (\nabla f)_p \cdot \frac{\bar{a}}{|a|}$$

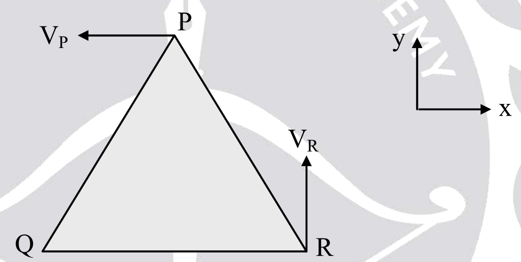
$$\Rightarrow \text{D.D} = (2x\bar{i} + 2x\bar{j}).\frac{(\bar{i}+\bar{j})}{\sqrt{1+1}}$$

$$\therefore \text{D.D} = \frac{2+2}{\sqrt{2}} = 2\sqrt{2}$$

Hence, option (A) is correct

End of Solution

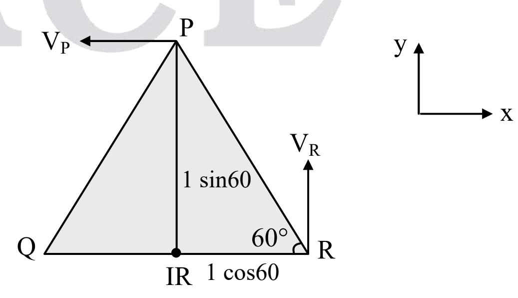
04. A rigid triangular body. PQR, with sides of equal length of 1 unit moves on a flat plane. At the instant shown, edge QR is parallel to the *x-axis*, and the body moves such that velocities of points P and R are V_p and V_R, in the x and y directions, respectively. The magnitude of the angular velocity of the body is



(A) $\frac{V_p}{\sqrt{3}}$ (B) $2V_p$ (C) $\frac{V_R}{\sqrt{3}}$ (D) $2V_R$

04. Ans: (D)

Sol:



$$\Rightarrow V_R = (IR)\omega$$

$$\Rightarrow \omega = \frac{V_R}{(IR)}$$

$$\Rightarrow \omega \times \frac{V_R}{\frac{1}{2}}$$

$$\Rightarrow \omega = 2\,V_R$$

05. The transformation matrix for mirroring a point in x - y plane about the line $y = x$ is given by

(A) $\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$ (B) $\begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix}$

(C) $\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ (D) $\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$

05. Ans: (D)

Sol: The transformation matrix for mirroring a point in x – y plane about the line y = x is

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

End of Solution

06. An analytic function f(z) of complex variable $z = x + iy$ may be written as $f(z) = u(x, y) + iv(x, y)$. Then, $u(x, y)$ and $v(x, y)$ must satisfy

(A) $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$ (B) $\frac{\partial u}{\partial x} = -\frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$

(C) $\frac{\partial u}{\partial x} = -\frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$ (D) $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$

06. Ans: (A)

Sol: Given that the complex function f(z)=u(x,y)+ i v(x,y) is an analytic function.

$\Rightarrow$ the Cauchy-Riemann equation will satisfy for u(x,y) & v(x,y)

$$\therefore \frac{\partial u}{\partial x} = \frac{\partial v}{\partial y} \;\&\; \frac{\partial v}{\partial x} = -\frac{\partial u}{\partial y}$$

Hence option (A) is correct.

End of Solution

07. In an electrical discharge machining process, the breakdown voltage across inter electrode gap (IEG) is 200 V and the capacitance of the RC circuit is 50 μF. The energy (in J) released per spark across the IEG is ______.

07. Ans: 1

Sol: Energy released = $\frac{1}{2}CV^2 = \frac{1}{2}\times 50\times 10^{-6}\times (200)^2 = 1J$

End of Solution

08. If x is the mean of data 3, x, 2 and 4, then the mode is _____.

08. Ans: 3

Sol: Given x is the mean of data

3, x, 2, 4

$\Rightarrow x = \frac{3+x+2+4}{4}$

$\Rightarrow 4x = 9 + x$

$\Rightarrow 3x = 9$

$\therefore x = 3$

Given data is 3, 2, 3, 4

We know that mode = The value of x which occurred more number of times

End of Solution

09. The differential equation $\frac{dy}{dx} + 4y = 5$ is valid in the domain $0 \le x \le 1$ with $y(0) = 2.25$.

The solution of the differential equation is

(A) $y = e^{-4x}+5$

(B) $y = e^{4x} + 1.25$

(C) $y = e^{-4x} + 1.25$

(D) $y = e^{4x} + 5$

09. Ans: (C)

Sol: Given $\frac{dy}{dx} + 4y = 5, 0 \le x \le 1$ ------- (1) $\because \frac{dy}{dx} + P(x, y) = Q(x)$

With y(0) = 2.25------------(2)

Here, I.F = $e^{\int 4dx} = e^{4x}$

The general solution of (1) is given by

$y.e^{4x} = \int(5)(e^{4x})dx + c$

$\Rightarrow y.e^{4x} = \frac{5}{4}e^{4x} + c$ ------ (3)

Using (2) and (3)

$(2.25)(1) = \left(\frac{5}{4}\right)(1) + c$

c = 1-------------(4)

The solution of (1) from (3) & (4) is

$y.e^{4x} = \frac{5}{4}e^{4x} + 1$ or $y = \frac{5}{4} + e^{4x} = 1.25 + e^{-4x}$

Hence, option (C) is correct

End of Solution

10. Hardenability of steel is a measure of

(A) the ability to retain its hardness when it is heated to elevate temperatures

(B) the depth to which required hardening is obtained when it is austenitized and then quenched

(C) the maximum hardness that can be obtained when it is austenitized and then quenched

(D) the ability to harden when it is cold worked

10. Ans: (B)

Sol: It is the depth to which required hardening is obtained when it is austenitized and then quenched. Hardenability is the ability of steel to form marteniste. The greater the hardenability the more martensite.

End of Solution

11. A two-dimensional incompressible frictionless flow field is given by $\bar{u} = x\hat{i} - y\hat{j}$. If ρ is the density of the fluid, the expression for pressure gradient vector at any point in the flow field is given as

(A) $\rho(x\hat{i} - y\hat{j})$

(B) $\rho(x\hat{i} + y\hat{j})$

(C) $-\rho(x\hat{i} + y\hat{j})$

(D) $-\rho(x^2\hat{i} + y^2\hat{j})$

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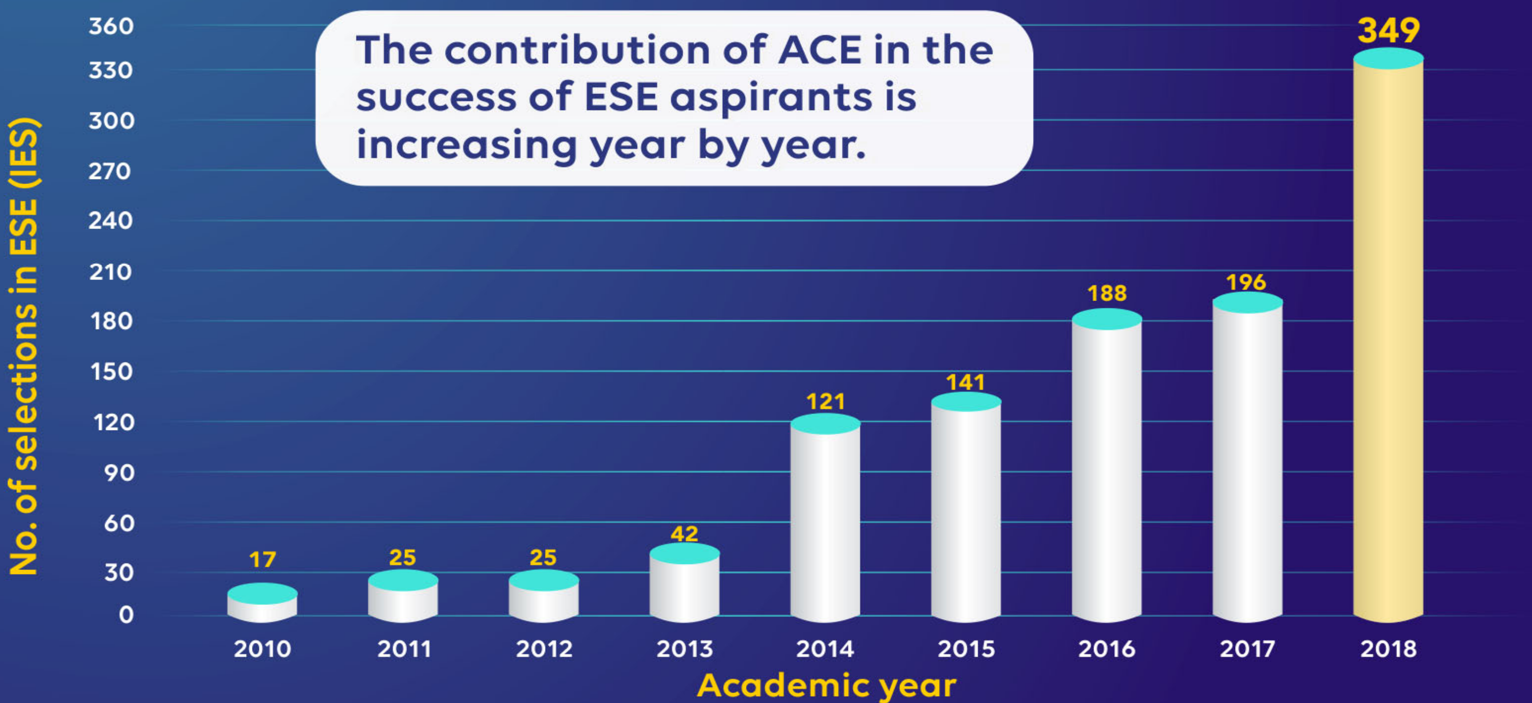

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11. Ans: (C)

Sol: Given, 2-D incompressible frictionless fluid flow.

$$\vec{u} = x\hat{i} - y\hat{j}$$

Thus, velocity components in x and y directions are :

u = x and v = -y

Navier-Stokes equation for incompressible, frictionless fluid flow reduces to

$$\rho \frac{D\vec{V}}{Dt} = -\nabla\vec{P} + \rho\vec{g}$$

There are no components of body force in x and y direction. Hence,

$$\rho \frac{D\vec{V}}{Dt} = -\nabla\vec{P}$$

where, $\nabla\vec{P}$ is the pressure gradient vector.

$$\text{Hence, } \nabla\vec{P} = -\rho\left[\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right)\hat{i} + \left(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right)\hat{j}\right]$$

$$= -\rho\left[\{x(1) + (-y)(0)\}\hat{i} + \{x(0) + (-y)(-1)\hat{j}\}\right]$$

$$= -\rho\left[x\,\hat{i} + y\,\hat{j}\right]$$

End of Solution

12. The most common limit gage used for inspecting the hole diameter is

(A) Ring gage
(B) Master gage
(C) Plug gage
(D) Snap gage

12. Ans: (C)

Sol: Plug gauges used for hole & Ring gauge used for shaft.

13. For a simple compressible system, *v, s, p* and T are specific volume, specific entropy, pressure and temperature, respectively. As per Maxwell's relations, $\left(\frac{\partial v}{\partial s}\right)_p$ is equal to

(A) $\left(\frac{\partial s}{\partial T}\right)_p$

(B) $-\left(\frac{\partial T}{\partial v}\right)_p$

(C) $\left(\frac{\partial T}{\partial p}\right)_s$

(D) $\left(\frac{\partial p}{\partial v}\right)_T$

13. Ans: (C)

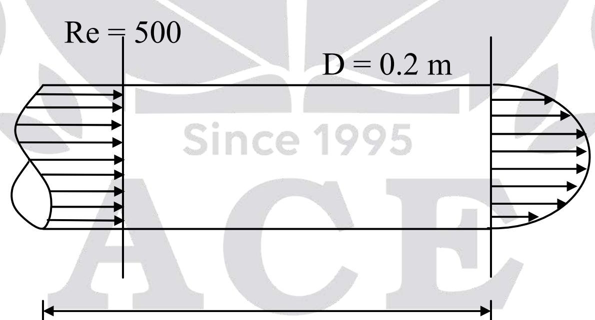
Sol: According to Maxwell's relation $\left(\frac{\partial v}{\partial s}\right)_p = \left(\frac{\partial T}{\partial p}\right)_s$

End of Solution

14. Water enters a circular pipe of length L = 5.0 m and diameter D = 0.20 m with Reyolds number R_{eD} = 500. The velocity profile at the inlet of the pipe is uniform while it is parabolic at the exit. The Reynolds number at the exit of the pipe is ____.

14. Ans: 500

Sol:



Given data,

Circular pipe, L = 5 m,

D = 0.2 m,

Re = 500 at inlet

At inlet velocity is uniform while at exit velocity profile is parabola.

Since diameter of the pipe does not change, the average velocity at exit will be the same as that at inlet, for the same discharge. This will result in Re to be same as that at inlet.

15. Consider a linear elastic rectangular thin sheet of metal, subjected to uniform uniaxial tensile stress of 100 MPa along the length direction. Assume plane stress conditions in the plane normal to the thickness. The Young's modulus E = 200 MPa and Poisson's ratio ν = 0.3 are given. The principal strains in the plane of the sheet are

(A) (0.5, –0.15) (B) (0.5, –0.5)

(C) (0.5, 0.0) (D) (0.35, –0.15)

15. Ans: (A)

Sol: $\sigma_x = 100$ MPa,

$\nu = \mu = 0.3$

$\sigma_y = 0$, $\sigma_z = 0$, E = 200 MPa

Principal strain in x-direction $= \epsilon_1 = \epsilon_x = \dfrac{\sigma_x}{E} - \mu\dfrac{\sigma_y}{E}$

$$= \frac{100}{200} - 0 = 0.5$$

Principal strain in y-direction $= \epsilon_2 = \epsilon_y = \dfrac{\sigma_y}{E} - \mu\dfrac{\sigma_x}{E}$

$$= 0 - (0.3)\left(\frac{100}{200}\right) = -0.15$$

$\therefore (\epsilon_x, \epsilon_y) = (0.5 - 0.15)$

End of Solution

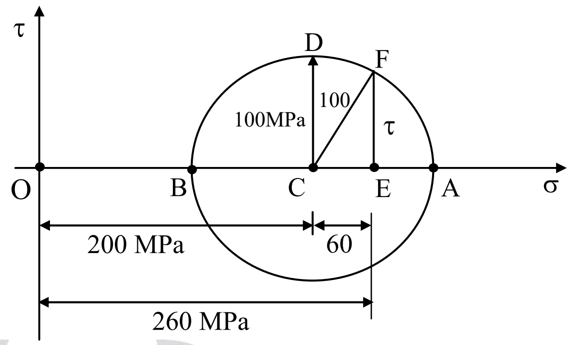
16. The state of stress at a point in a component is represented by a Mohr's circle of radius 100 MPa centered at 200 MPa on the normal stress axis. On a plane passing through the same point, the normal stress is 260 MPa. The magnitude of the shear stress on the same plane at the same point is _____ MPa.

16. Ans: 80

Sol: In triangle CEF

$CF^2 = CE^2 + EF^2$

$100^2 = 60^2 = EF^2$



$EF^2 = 100^2 - 60^2 = 6400$

EF = 80 MPa

EF → Represents shear stress at the same point = EF = τ = 80 MPa

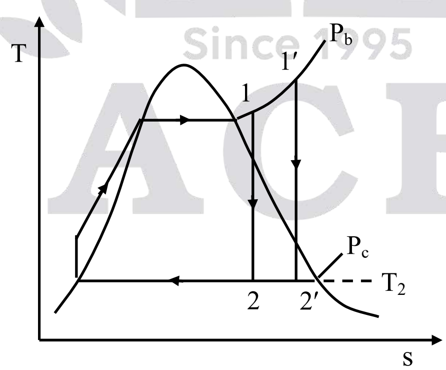
End of Solution

17. Which one of the following modifications of the simple ideal Rankine cycle increases the thermal efficiency and reduces the moisture content of the steam at the turbine outlet?

(A) Increasing the boiler pressure
(B) Increasing the turbine inlet temperature
(C) Decreasing the condenser pressure
(D) Decreasing the boiler pressure

17. Ans: (B)

Sol: Rankine cycle efficiency can be increased by increasing the mean temperature of heat addition and it can be obtain by increasing the super heated temperature of steam at the inlet to the steam turbine



While the superheated steam temperature increases, the dryness fraction increases (i.e., moisture content decreases).

18. Endurance limit of a beam subjected to pure bending decreases with

(A) increase in the surface roughness and increase in the size of the beam

(B) increase in the surface roughness and decrease in the size of the beam

(C) decrease in the surface roughness and decrease in the size of the beam

(D) decrease in the surface roughness and increase in the size of the beam

18. Ans: (A)

Sol: Endurance limit decreases with increase in surface roughness and with increase in size of the beam.

End of Solution

19. In matrix equation [A] {X} = {R}.

$$[A]=\begin{bmatrix}4 & 8 & 4\\ 8 & 16 & -4\\ 4 & -4 & 15\end{bmatrix}, \{X\}=\begin{Bmatrix}2\\1\\4\end{Bmatrix} \text{ and } \{R\}=\begin{Bmatrix}32\\16\\64\end{Bmatrix}$$

One of the eigen values of matrix [A] is

(A) 16
(B) 15
(C) 4
(D) 8

19. Ans: (A)

Sol: Given that AX=R

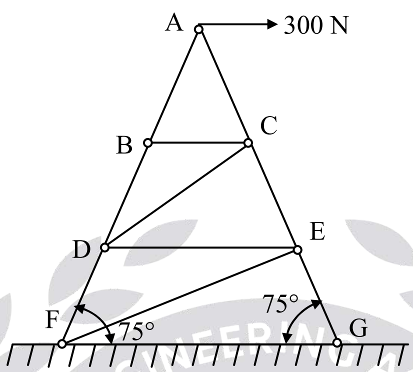
$$\Rightarrow \begin{bmatrix}4 & 8 & 4\\ 8 & 16 & -4\\ 4 & -4 & 15\end{bmatrix}\begin{bmatrix}2\\1\\4\end{bmatrix}=\begin{bmatrix}32\\16\\64\end{bmatrix}$$

$$\Rightarrow \begin{bmatrix}4 & 8 & 4\\ 8 & 16 & -4\\ 4 & -4 & 15\end{bmatrix}\begin{bmatrix}2\\1\\4\end{bmatrix}=16\begin{bmatrix}32\\1\\4\end{bmatrix} \quad ((\because AX=\lambda X)$$

$\therefore$ One of eigen value of the given matrix A is given by $\lambda = 16$

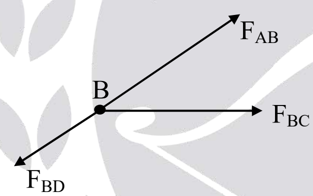
Hence, option (A) is correct.

20. The figure shows an idealized plane truss. If a horizontal force of 300 N is applied at point *A*, then the magnitude of the force produced in member CD is _______ N.



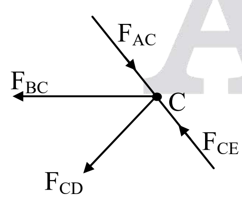
20. Ans: 0

Sol:



Adopting method of joints and taking FBD of joint B

$F_{BC} = 0$ (zero force member)



Further by taking FBD of joint C

$F_{CD} = 0$

21. A wire of circular cross-section of diameter 1.0 mm is bent into a circular arc of radius 1.0 m by application of pure bending moments at its ends. The Young's modulus of the material of the wire is 100 GPa. The maximum tensile stress developed in the wire is ______ MPa.

21. Ans: 50

Sol: d = 1.0 mm

$$y_{max} = \frac{d}{2} = \frac{1.0}{2} = 0.5 \text{ mm}$$

R = 1.0m = 1000 mm

E = 100 GPa = 100×10^3 MPa

From bending equation, $\frac{f_{max}}{y_{max}} = \frac{E}{R}$

$$f_{max} = y_{max}\cdot\frac{E}{R}$$

$$= 0.5\times\frac{100\times10^3}{1000} = 50 \text{ MPa}$$

$\therefore f_{max} = 50$ MPa

End of Solution

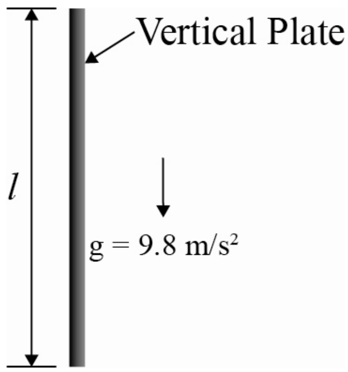
22. The cold forming process in which a hardened tool is pressed against a workpiece (when there is relative motion between the tool and the workpiece) to produce a roughened surface with a regular pattern is

(A) Knurling
(B) Strip rolling
(C) Chamfering
(D) Roll forming

22. Ans: (A)

Sol: Knurling is the process of producing a straight angled cross lines by rolling using lathe machine. It is done by using one or more hard rollers that contain reverse of the pattern to be imposed.

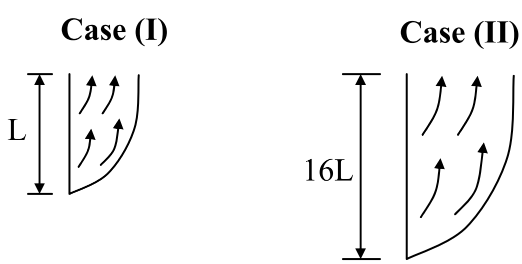
23. A thin vertical flat plate of height L, and infinite width perpendicular the plane of the figure, is losing heat to the surroundings by natural convection. The temperatures of the plate and the surroundings, and the properties of the surrounding fluid, are constant. The relationship between the average Nusselt and Rayleigh numbers is given as $Nu = KRa^{1/4}$, where K is a constant. The length scales for Nusselt and Rayleigh numbers are the height of the plate. The height of the plate increased to 16 L keeping all other factors constant.



If the average the heat transfer coefficient for the first plate is h_1 and that for the second plate is h_2, the value of the ratio h_1/h_2 is __________.

23. Ans: 2

Sol:



$Nu = K\,(Ra)^{1/4}$

$Nu = K\,(Gr.\,Pr)^{1/4}$

$Nu \propto (Gr)^{1/4}$

$$Nu \propto \left(\frac{g\beta\Delta TL^3}{\nu^2}\right)^{1/4}$$

$Nu \propto L^{3/4}$

$\frac{h.L}{K} \propto L^{3/4}$

$h \propto L^{3/4-1}$

$h \propto L^{-1/4}$

$$\frac{h_1}{h_2} = \left(\frac{L_1}{L_2}\right)^{-1/4} = \left(\frac{L}{16L}\right)^{-1/4} = \left(\frac{1}{16}\right)^{-1/4}$$

$$\frac{h_1}{h_2} = 2$$

End of Solution

24. The fluidity of molten metal of cast alloys (without any addition of fluxes) increases with increase in

(A) surface tension
(B) degree of superheat
(C) viscosity
(D) freezing range

24. Ans: (B)

Sol: Fluidity increases with increase of degree super heat.

End of Solution

25. A spur gear has pitch circle diameter *D* and number of teeth *T*. The circular pitch of the gear is

(A) $\frac{T}{D}$
(B) $\frac{D}{T}$
(C) $\frac{2\pi D}{T}$
(D) $\frac{\pi D}{T}$

25. Ans: (D)

Sol: Circular pitch : It is the distance between two similar points on adjacent teeth measured along pitch circle circumference circular pitch (P_c) = $\frac{\text{Pitch circle circum}}{\text{Number of teeth}} = \frac{\pi D}{T}$

26. A gas tungsten arc welding operation is performed using a current of 250 A and an arc voltage of 20 V at a welding speed of 5 mm/s. Assuming that the efficiency is 70%, the net heat input per unit length of the weld will be _______ kJ/mm (round off to one decimal place).

26. Ans: 0.7

Sol: GTAW, current I = 250 A ,

Voltage, V = 20 V,

Speed, ν = 5 mm/sec,

Arc efficiency, η = 0.7

Duty cycle, D = 1 (not given)

Heat input per unit length, $\frac{H}{\ell} = \frac{\eta D V I}{\nu}$

$$= \frac{0.7 \times 1 \times 250 \times 20}{5}$$

= 700 J/mm = 0.7 kJ/mm

End of Solution

27. The derivative of *f(x)* = cos(*x*) can be estimated using the approximation $f'(x) = \frac{f(x+h) - f(x-h)}{2h}$.

The percentage error is calculated as $\left(\frac{Exact\,value - approximate\,value}{Exact\,value}\right) \times 100$. The percentage error in the derivative of f(*x*) at *x* = π/6 radian, choosing *h* = 0.1 radian, is

(A) > 5%
(B) > 0.1% and < 1%
(C) > 1% and < 5%
(D) < 0.1%

27. Ans: (B)

Sol: Given f(x) = cos(x), $x = \frac{\pi}{6}$ radians & h = 0.1 radian

$\Rightarrow f^1(x) = -\sin(x)$

$\Rightarrow f^1(x) = -\sin(x)$ at $x = \frac{\pi}{6}$ is $f^1\left(\frac{\pi}{6}\right) = -\sin\left(\frac{\pi}{6}\right) = \frac{-1}{2}$

$\therefore$ The exact value of the directive of f(x) at $x = \frac{\pi}{6}$ is $f^1\left(\frac{\pi}{6}\right) = \frac{-1}{2}$

The approximate value of the directive of f(x) at $x = \frac{\pi}{6}$ with h=0.1 is given by

$$\frac{f(x+h)-f(x-h)}{2h} = \frac{\cos(x+h)-\cos(x-h)}{2h}$$

$$\Rightarrow \frac{f(x+h)-f(x-h)}{2h} = \frac{(\cos(x)\cosh - \sin x \sinh) - (\cos(h)\cos x + \sin(x)\sinh)}{2h}$$

$$\Rightarrow \frac{f(x+h)-f(x-h)}{2h} = \frac{-2\sin(x)\sin(h)}{2h} = -0.499$$

$\therefore$ The percentage error in the directive of f(x)

At $x = \frac{\pi}{e}$ & h=0.1 is given by

$$\frac{\text{Exact value} - \text{Approximately value}}{\text{Exact time}} \times 100 = \frac{\left(\frac{-1}{2}\right) - (-0.499)}{\left(\frac{-1}{2}\right)} \times 100$$

$$= 0.166\%$$

i.e., 0.1% < 0.166% < 1%

Hence, option (B) is correct.

End of Solution

28. The annual demand of valves per year in a company is 10,000 units. The current order quantity is 400 valves per order. The holding cost is Rs. 24 per valve per year and the ordering cost is Rs. 400 per order. If the current order quantity is changed to Economic Order Quantity, then the saving in the total cost of inventory per year will be Rs. _______ (round off two decimal places).

28. Ans: 943.6

Sol: Annual demand (D) = 10000 units

Holding cost (C_c) = 24 /unit / year

Ordering cost (C_0) = 400 /order

Order quantity (Q) = 400 units

$$TC|_{Q=400} - TC|_{EOQ} = \left[\frac{Q}{2}\times C_C + \frac{D}{Q}\times C_0\right] - \left[\sqrt{2DC_0C_c}\right]$$

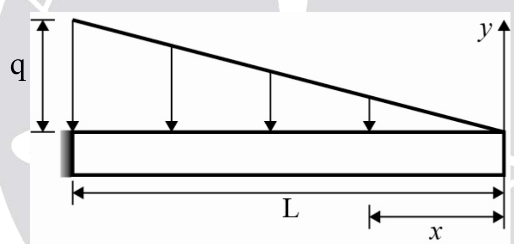
$$= \left[\frac{400}{2}\times 24 + \frac{10000}{400}\times 400\right] - \left[\sqrt{2\times 10000\times 400\times 24}\right]$$

$$= (4800 + 10000) - (13856)$$

$$= 943.60$$

End of Solution

29. A prismatic, straight, elastic, cantilever beam is subjected to a linearly distributed transverse load as shown below. If the beam length is *L*, Young's modulus *E*, and area moment of inertia *I*, the magnitude of the maximum deflection is



(A) $\frac{qL^4}{30EI}$ (B) $\frac{qL^4}{15EI}$

(C) $\frac{qL^4}{10EI}$ (D) $\frac{qL^4}{60EI}$

29. Ans: (A)

Sol: Double Integration method:

Let x be distance from the free end

$$M_x = -\left(\frac{1}{2}\times x\times\frac{qx}{L}\right)\left(\frac{x}{3}\right)$$

$$= -\frac{qx^3}{6L}$$

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3	PRAVEEN KUMAR	CE
3	MAYUR PATIL	ME
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4	ANKIT GARG	EE
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5	RISHABH DUTT	CE
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6	KUMUD JINDAL	E&T
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7	KARTIKEYA DUTTA	E&T
7	TEKCHAND DESHWAL	EE
7	ROHIT KUMAR	CE
8	SURYASH GAUTAM	E&T
8	RAVI TEJA MANNE	EE
8	VIJAYA NANDAN	CE
8	ROHIT BANSAL	ME
9	SHANAVAS CP	E&T
9	SOUVIK DEB ROY	EE
9	ROOPESH MITTAL	CE
10	PRATHAMESH	E&T
10	MILAN KRISHNA	EE
10	SRICHAND POONIYA	CE

TOTAL SELECTIONS in Top 10	34

	TOP 10
E&T	10
EE	10
CE	8
ME	6

and many more...

$$EI.\frac{d^2y}{dx^2} = -\left(\frac{qx^3}{6L}\right)$$

$$EI.\frac{dy}{dx} = -\frac{qx^4}{24L} + C_1 \rightarrow \text{Slope equation---(1)}$$

$$EI.y = -\frac{qx^5}{120L} + C_1x + C_2 \rightarrow \text{Deflection equation ----(2)}$$

Boundary Conditions: (a) Fixed end, x = L, $\theta_A = 0$; $Y_A = 0$

$$\therefore \quad \text{from (1) } 0 = -\frac{qL^4}{24L} + C_1 \Rightarrow C_1 = \frac{qL^3}{24}$$

$$\text{from (2) } 0 = -\frac{qL^5}{120L} + \frac{qL^3}{2L}(L) + C_2$$

$$\Rightarrow C_2 = \frac{qL^4}{30}$$

$\therefore$ maximum deflection at free end i.e. at x = 0

$$\therefore\ y_{max} = \frac{C_2}{EI} = \frac{qL^4}{30EI}$$

End of Solution

30. The aerodynamic drag on a sports car depends on its shape. The car has a drag coefficient of 0.1 with the windows and the roof closed. With the windows and the roof open, the drag coefficient becomes 0.8. The car travels at 44 km/h with the windows and roof closed. For the same amount of power needed to overcome the aerodynamic drag, the speed of the car with the windows and roof open (round off to two decimal places), is ________ km/h (The density of air and the frontal area may be assumed to be constant).

30. Ans: 22.00

Sol: Given data :

(i) When the windows and roof of the car are closed $(C_D)_C = 0.1$ and $V_c = 44$ km/h

(ii) When the windows and roof of the car are open, $(C_D)_0 = 0.8$ and $V_0 = ?$

(iii) $\rho_c = \rho_0$, $A_c = A_0$ and $P_c = P_0$ where P is the power required to overcome the aerodynamic drag.

We know that,

$$P = F_D \times V = C_D \times \frac{1}{2}\rho A V^2 \times V = \frac{1}{2} C_D \rho A V^3$$

For ρ and A to be constant,

$P \propto C_D V^3$

Also, P is the same for both cases.

Hence, $C_D V^3$ = constant

or $$\frac{V_O}{V_C} = \left(\frac{C_{DC}}{C_{DO}}\right)^{1/3} = \left(\frac{0.1}{0.8}\right)^{1/3} = \frac{1}{2}$$

$$\Rightarrow V_O = \frac{V_C}{2} = \frac{44}{2} = 22.00 \text{ km/h}$$

End of Solution

31. A through hole is drilled in an aluminum alloy plate of 15 mm thickness with a drill bit of diameter 10 mm, at a feed of 0.25 mm/rev and a spindle speed of 1200 rpm. If the specific energy required for cutting this material is 0.7 N.m/mm^3, the power required for drilling is ______ W (round off to two decimal places).

31. Ans: 274.75

Sol: Given data

t = thickness = 15 mm

d = dia of drill = 10 mm

f = 0.25 mm/rev

Speed, N = 1200 rpm

Specific cutting energy = 0.7 J/mm^3

$$\text{S.P.C.E.} = \frac{\text{Power}}{\text{MRR}}$$

$$\text{Power} = \text{MRR} \times \text{S.P.C.E} = \text{Area of drill} \times (\text{Feed/sec}) \times \text{S.P.C.E} = \frac{\pi}{4} d^2 \times \frac{f}{60} \times N \times \text{S.P.C.E}$$

$$= \frac{\pi}{4} \times 10^2 \times \frac{0.25}{60} \times 1200 \times 0.7 = 274.75 \text{ W}$$

32. A ball of mass 3 kg moving with a velocity of 4 m/s undergoes a perfectly-elastic direct-central impact with a stationary ball of mass *m*. After the impact is over, the kinetic energy of the 3 kg ball is 6 J. The possible value(s) of *m* is/are

(A) 6 kg only
(B) 1 kg only
(C) 1 kg, 6 kg
(D) 1 kg, 9 kg

32. Ans: (D)

Sol: Let V_1 is the speed of 3 kg mass after collision

V_2 is the speed of m kg mass after collision

$$e = 1 = \frac{V_2 - V_1}{4}$$

$$\Rightarrow V_2 - V_1 = 4 \quad \text{------------- (1)}$$

By linear momentum conservation

$$3 \times 4 = 3V_1 + mV_2 \quad \text{------- (2)}$$

$$\frac{1}{2} \times 3 \times V_1^2 = 6$$

$$\Rightarrow V_1 = \pm 2 \quad \text{--------- (3)}$$

By using (1), (2) & (3) we get

m = 1 kg (or) 9 kg

End of Solution

33. A differential equation is given as $x^2 \frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = 4$. The solution of the differential equation in terms of arbitrary C_1 and C_2 is

(A) $y = C_1x^2 + C_2x + 2$
(B) $y = \frac{C_1}{x^2} + C_2x + 4$
(C) $y = C_1x^2 + C_2x + 4$
(D) $y = \frac{C_1}{x^2} + C_2x + 2$

33. Ans: (A)

Sol: Given $(x^2 D^2 - 2xD + 2)y=4$ ------ (1) where $D = \frac{d}{dx}$

Let $x = e^z$ or $\log x = z$ & $xD = \theta$, $x^2D^2 = \theta(\theta^2-1)$ ------ (2) Where $\theta = \frac{d}{dz}$

Using (2), (1) becomes

$[\theta(\theta-1) - 2\theta + 2]y=4$

$\Rightarrow (\theta^2-3\theta+2)y=4$

$\Rightarrow f(\theta)y = Q(z)$, where $f(\theta)=\theta^2-3\theta+2$ & $Q(z) = 4$

C.F:

Auxiliary equation if $f(m)=0$

$\Rightarrow m^2 - 3m + 2 = 4$

$\Rightarrow m = 1, 2$

$\Rightarrow y_c=c_1e^{2z} + c_2e^z$

$y_c=c_1 x^2 + c_2 x$

P.I:

$\theta(z) = 4 = 4.e^{0z} = ke^{az+b}$

Here, $f(\theta) = f(a) = f(0) = 0 - 0 + 2 = 2$

$\therefore y_p = \frac{1}{f(a)}\theta(z) = \frac{1}{2}4 = 2$

Hence, the solution of (1) is $y = y_c+y_p$

i.e., $y= (c_1 x^2+c_2x) + 2$

Here, option (A) is correct.

34. Three set of parallel plates LM, NR and PQ are given in Figures 1, 2 and 3. The view factor F_{IJ} is defined as the fraction of radiation leaving plate *I* that is intercepted by plate *J*. Assume that the values of F_{LM} and F_{NR} are 0.8 and 0.4 respectively. The value of F_{PQ} (round off to one decimal place) is ______.

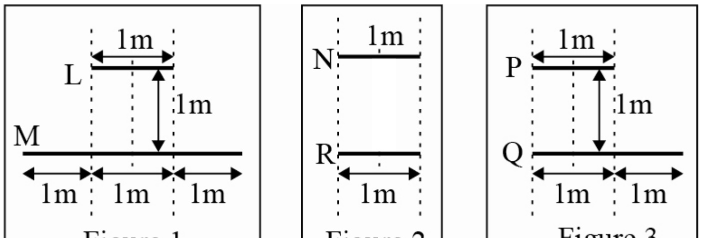


Figure 1 Figure 2 Figure 3

34. Ans: 0.6

Sol:

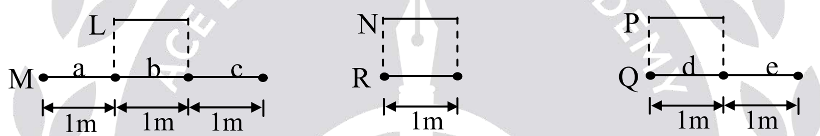


Fig: 1 *Fig: 2* *Fig: 3*

$F_{LM} = F_{L\text{-}a} + F_{L\text{-}b} + F_{L\text{-}c} = 0.8$ -------- (1)

$F_{N\text{-}R} = 0.4$

From the figure,

$F_{L\text{-}a} = F_{L\text{-}c} = F_{P\text{-}e}$ (similar)

$F_{L\text{-}b} = F_{N\text{-}R}$ (similar)

From equation (1)

$F_{L\text{-}a} + F_{L\text{-}b} + F_{L\text{-}c} = 0.8$

$2 \times F_{L\text{-}a} + F_{N\text{-}R} = 0.8$

$$F_{L-a} = \frac{0.8 - 0.4}{2} = 0.2$$

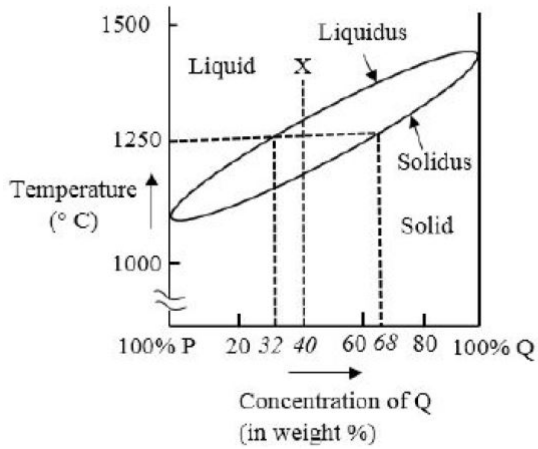
From the fig – 3

$F_{P\text{-}Q} = F_{P\text{-}d} + F_{P\text{-}e} = F_{N\text{-}R} + F_{L\text{-}a}$ [$F_{P\text{-}d} = F_{N\text{-}R}$ & $F_{P\text{-}e} = F_{L\text{-}a}$ (due to similarity)]

$= 0.4 + 0.2$

$F_{P\text{-}Q} = 0.6$

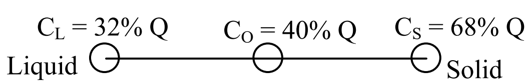
35. The binary phase diagram metals P and Q is shown in the figure. An alloy X containing 60% P and 40% Q (by weight) is cooled from liquid to solid state. The fractions of solid and liquid (in weight percent) at 1250°C, respectively, will be



(A) 68.0% and 32.0%
(B) 32.0% and 68.0%
(C) 22.2% and 77.8%
(D) 77.8% and 22.2%

35. Ans: (C)

Sol: Lever line :



Mass friction of solid $= \dfrac{c_o - c_L}{c_s - c_L}$

$$= \frac{40-32}{68-32}$$

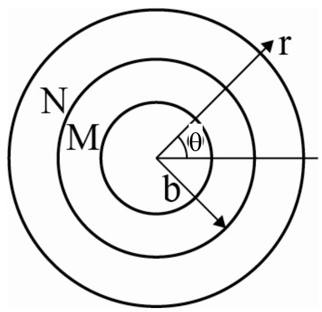
$$m_s = \frac{8}{36} = 0.2222 \approx 22.2\ \%$$

Mass friction of liquid $= \dfrac{c_S - c_O}{c_S - c_L}$

$$= \frac{68-40}{68-32}$$

$$(m_\ell) = \frac{28}{36} = 0.777 \approx 77.8\ \%$$

36. Consider two concentric circular cylinders of different materials M and N in contact with each other at r = b, as shown below. The interface at r = b is frictionless. The composite cylinder system is subjected to internal pressure P. Let $\left(u_r^M, u_\theta^M\right)$ and $\left(\sigma_{rr}^M, \sigma_{\theta\theta}^M\right)$ denote the radial and tangential displacement and stress components, respectively, in material M. Similarly, $\left(u_r^N, u_\theta^N\right)$ and $\left(\sigma_{rr}^N, \sigma_{\theta\theta}^N\right)$ denote the radial and tangential displacement and stress components respectively, in material N. The boundary conditions that need to be satisfied at the frictionless interface between the two cylinders are:



(A) $\sigma_{rr}^M = \sigma_{rr}^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only

(B) $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$ and $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^M$

(C) $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only

(D) $u_r^M = u_r^N$ *and* $\sigma_{rr}^M = \sigma_{rr}^N$ only

36. Ans: (D)

Sol: As the contact is frictionless, one cylinder can rotate freely with respect other. The displacement in tangential directions need not be same at a point contact for two cylinders $\left(i.e., u_\theta^M \neq u_\theta^N\right)$. Similarly the Hoop stress at point of contact need not be same $\left(i.e., \sigma_{\theta\theta}^M \neq \sigma_{\theta\theta}^N\right)$. As the interface will be always in contact the displacement in radial direction and stress in radial directions must be same for two cylinders. i.e., $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$.

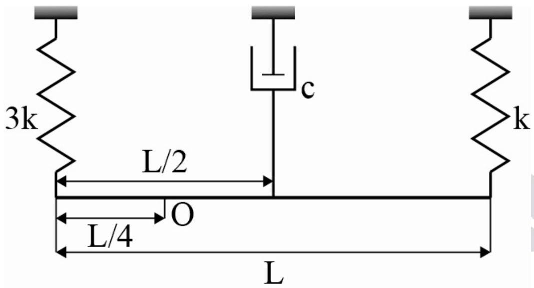
37. A slender uniform rigid bar of mass *m* is hinged at O and supported by two springs, with stiffnesses $3k$ and k, and a damper with damping coefficient c, as shown in the figure. For the system to be critically damped, the ratio $c/\sqrt{km}$ should be

(A) $2\sqrt{7}$

(B) $4\sqrt{7}$

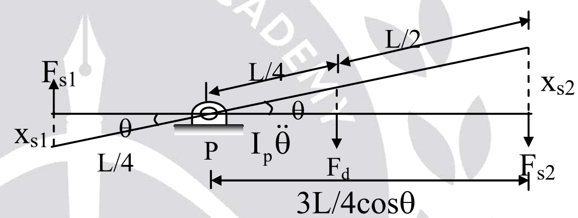
(C) 4

(D) 2



37. Ans: (B)

Sol: $x_{s_1} = \frac{L}{4}\sin\theta \approx \frac{L}{4}\theta$



$$x_{s_2} = \frac{3L}{4}\sin\theta \approx \frac{3L}{4}\theta$$

$$x_d = \frac{L}{4}\sin\theta \approx \frac{L}{4}\theta$$

$$\dot{x}_d = \frac{L}{4}\dot{\theta}$$

Taking moment about 'P'

$$\Rightarrow I_p\ddot{\theta} + c\dot{x}_d\frac{L}{4} + kx_{s_2}.\frac{3L}{4} + 3kx_{s_1}\frac{L}{4} = 0$$

$$\Rightarrow I_p\ddot{\theta} + C\left(\frac{L}{4}\right)^2\dot{\theta} + k\left(\frac{3L}{4}\right)^2\theta + 3k\left(\frac{L}{4}\right)^2\theta = 0$$

$$\Rightarrow I_p\ddot{\theta} + \frac{CL^2}{16}\dot{\theta} + \left(\frac{9L^2k}{16} + \frac{3kL^2}{16}\right)\theta = 0$$

$$\Rightarrow I_p\ddot{\theta} + \frac{CL^2}{16}\dot{\theta} + \frac{3}{4}kL^2\theta = 0$$

$$I_{eq} = I_p = \frac{m\ell^2}{12} + \frac{m\ell^2}{16} = I_p = \frac{7}{48}ml^2,$$

$$C_{eq} = \frac{C\ell^2}{16}$$

$$k_{eq} = \frac{3k\ell^2}{4}$$

$$\omega_n = \sqrt{\frac{k_{eq}}{I_p}} = \sqrt{\frac{3k\ell^2}{4\times\frac{7m\ell^2}{48}}} = \sqrt{\frac{36k}{7m}}$$

$$\omega_{n=} = 6\sqrt{\frac{k}{7m}}$$

$$\zeta = \frac{C_{eq}}{2I_{eq}\omega_n} = \frac{C\ell^2}{2\times16\times\frac{7\ell^2}{48}\times6\sqrt{\frac{k}{7m}}}$$

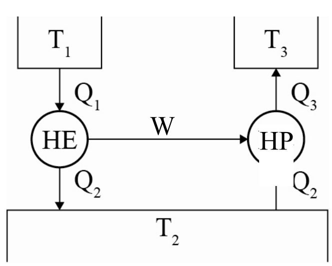
$$2\times16\times\frac{7\times6^2}{48\sqrt{7}} = \frac{C}{\sqrt{k.m}}$$

$$\frac{C}{\sqrt{km}} = 2\times2\sqrt{7} = 4\sqrt{7}$$

End of Solution

38. The figure shows a heat engine (HE) working between two reservoirs. The amount of heat (Q_2) rejected by the heat engine is drawn by a heat pump (HP). The heat pump receives the entire work output (W) of the heat engine. If temperatures, $T_1 > T_3 > T_2$, then the relation between the efficiency (η) of the heat engine and the coefficient of performance (COP) of the heat pump is

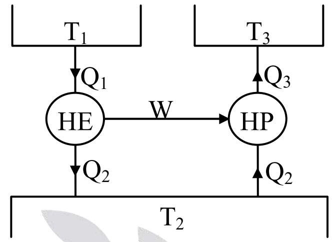
(A) COP = η
(B) COP = $\eta^{-1} - 1$
(C) COP = η^{-1}
(D) COP = $1 + \eta$



38. Ans: (C)

Sol:

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



$$\frac{Q_2}{Q_1} = 1 - \eta ....(I)$$

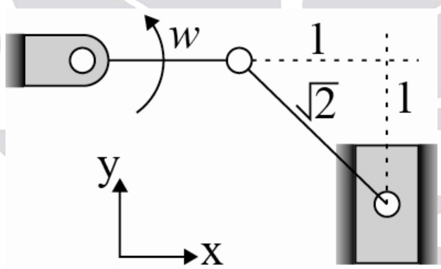
$$\Rightarrow W = Q_1 - Q_2 = Q_3 - Q_2 ....(II)$$

$$COP = \frac{RE}{W} = \frac{Q_3}{Q_1 - Q_2}$$

$$= \frac{Q_3/Q_1}{1 - \frac{Q_2}{Q_1}} = \frac{1}{\eta}$$

End of Solution

39. The crank of a slider-crank mechanism rotates counter-clockwise (CCW) with a constant angular velocity ω, as shown. Assume the length of the crank to be r,



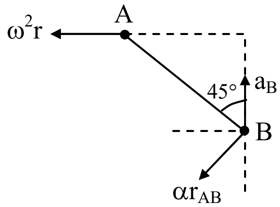
Using exact analysis, the acceleration of the slider in the y-direction, at the instant shown, where the crank is parallel to x-axis, is given by

(A) $-\omega^2 r$ (B) $-2\omega^2 r$

(C) $\omega^2 r$ (D) $2\omega^2 r$

39. Ans: (C)

Sol:



Since the velocity of the point A and B are parallel $\omega_{AB} = 0$.

$$\vec{a}_B = \vec{a}_A + \vec{a}_{AB}$$

$$\vec{a}_B = a_B \hat{j}$$

$$\vec{a}_A = -\omega^2 r \hat{i}$$

$$\vec{a}_{AB} = -\alpha r_{AB} \sin 45 \hat{i} - \alpha r_{AB} \cos 45 \hat{j} \quad (\because \omega^2 r_{AB} \text{ along link AB} = 0)$$

$$a_B \hat{j} = -\omega^2 r \hat{i} - \left(\alpha \hat{i} + \alpha \hat{j}\right) \qquad = -\left(\omega^2 r + \alpha\right)\hat{i} - \alpha \hat{j}$$

$$\omega^2 r + \alpha = 0$$

$$\alpha = -\omega^2 r$$

$$a_B = -\alpha = -(-\omega^2 r) = \omega^2 r$$

End of Solution

40. Water flowing at the rate of 1 kg/s through a system is heated using an electric heater such that the specific enthalpy of the water increases by 2.50 kJ/kg and the specific entropy increases by 0.007 kJ/kg.K. The power input to the electric heater is 2.50 kW. There is no other work or heat interaction between the system surroundings. Assuming an ambient temperature of 300 K, the irreversibility rate of the system is _______ kW (round off to two decimal places).

40. Ans: 2.10

Sol: Given:

$$\left(h_2 - h_1\right)_{water} = 2.5 \, kJ/kg$$

$$\left(s_2 - s_1\right)_{water} = 0.007 \, kJ/kg \, K$$

$$[\text{Power}]_{input} = 2.5 \, kW$$

$T_0 = 300$ K

$[\text{Power}]_{\text{input}} = \dot{m}(h_2 - h_1)_{\text{water}}$

$2.5 = \dot{m}(2.5)$

$\dot{m} = 1\,\text{kg/s}$

$(ds)_{\text{water}} = \dot{m}(s_2 - s_1)_{\text{water}} = 0.007$ kW/K

$(ds)_{\text{surrounding}} = 0$

$(ds)_{\text{universe}} = 0.007\,\text{kW/K}$

Irreversibility = 300×0.007 = 2.1 kW

End of Solution

41. The probability that a part manufactured by a company will be defective is 0.05. If 15 such parts are selected randomly and inspected, then the probability that at least two parts will be defective is ______ (round off to decimal places).

41. Ans: 0.1709

Sol: Let p = probability of making defective part

= 0.05

$\Rightarrow$ q = 1 – p = 0.95

given n = 15

Let X be number of defective parts be a random variable.

$P(X \geq 2) = 1 - P(X < 2)$

$= 1 - \{P(X = 0) + P(X = 1)\}$

$= 1 - ({}^{15}C_0\, p^0 q^n + {}^{15}C_1\, p^1 q^{14})$

$= 1 - \{(0.95)^{15} + 15(0.05)(0.95)^{14})\}$

$= 0.1709$

ESE / GATE / PSUs - 2020
ADMISSIONS OPEN

CENTER	COURSE	BATCH TYPE	DATE
HYDERABAD - DSNR	GATE + PSUS – 2020	Regular Batches	26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - DSNR	ESE + GATE + PSUs - 2020	Regular Batches	21st March, 26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - DSNR	GATE + PSUs - 2020	Short Term Batches	29th April, 6th, 11th, 18th May 26th May, 2nd June, 2019
HYDERABAD - DSNR	GATE + PSUs - 2020	Morning/Evening Batch	24th February 2019
HYDERABAD - DSNR	ESE – 2019 STAGE-II (MAINS)	Regular Batch	17th Feb 2019
HYDERABAD - Abids	GATE + PSUS – 2020	Regular Batches	26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - Abids	GATE + PSUs - 2020	Short Term Batches	29th April, 6th, 11th, 18th May 26th May, 2nd June, 2019
HYDERABAD - Abids	ESE + GATE + PSUs - 2020	Morning Batch	24th February 2019
HYDERABAD - Abids	ESE – 2019 STAGE-II (MAINS)	Regular Batch	17th Feb 2019
HYDERABAD - Abids	GATE + PSUs - 2020	Weekend Batch	24th February 2019
HYDERABAD - Abids	ESE+GATE + PSUs - 2020	Spark Batches	11th May, 09th June 2019
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Morning/Evening Batch	24th February 2019
HYDERABAD - Kukatpally	GATE + PSUS – 2020	Regular Batches	17th May, 1st, 16th June, 1st July 2019
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Short Term Batches	29th April, 6th, 11th, 18th May 26th May, 2nd June, 2019
HYDERABAD - Kothapet	ESE + GATE + PSUS – 2020	Regular Batches	21st March, 26th April, 11th, 25th May, 09th, 24th June, 8th July 2019
HYDERABAD - Kothapet	ESE+GATE + PSUs - 2020	Spark Batches	11th May, 09th June 2019
DELHI	ESE+GATE+PSUs - 2020	Weekend Batches	9th Mar 2019
DELHI	ESE+GATE+PSUs - 2020	Regular Evening Batch	18th Feb 2019
DELHI	ESE+GATE+PSUs - 2020	Regular Day Batch	11th May 2019
DELHI	ESE+GATE+PSUs - 2020	Spark Batch	11th May 2019
DELHI	GATE+PSUs - 2020	Short Term Batches	11th, 23rd May 2019
BHOPAL	ESE+GATE+PSUs - 2020	Regular Day Batch	01st Week of June 2019
BHUBANESWAR	GATE+PSUs - 2020	Weekend Batch	16th Feb 2019
BHUBANESWAR	GATE+PSUs - 2020	Regular Batch	02nd Week of May 2019
CHENNAI	GATE+PSUs - 2020 & 21	Weekend Batch	16th Feb 2019
CHENNAI	GATE+PSUs - 2020	Regular Batch	02nd Week of May 2019
BANGALORE	GATE+PSUs - 2020 & 21	Weekend Batch	23rd Feb 2019
BANGALORE	GATE+PSUs - 2020	Regular Batch	17th June 2019

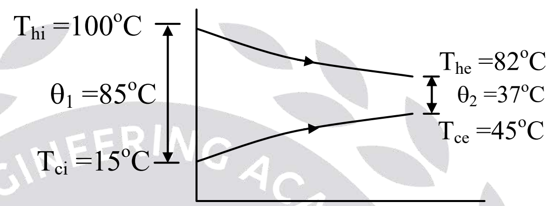
42. Hot and cold fluids enter a parallel flow double tube heat exchanger at 100°C and 15°C, respectively. The heat capacity rates of hot and cold fluids are C_h = 2000 W/K and C_c = 1200 W/K, respectively. If the outlet temperature of the cold fluid is 45°C, the log mean temperature difference (LMTD) of the heat exchanger is _______ K (round off to two decimal places).

42. Ans: 57.71

Sol: Given data:

$C_h = 2000$ W/K

$C_c = 1200$ W/K



Energy balance:

Energy released by hot fluid = Energy received by cold fluid

$C_h (T_{hi} - T_{he}) = C_c (T_{ce} - T_{ci})$

$2000(100 - T_{he}) = 1200 (45 - 15)$

$2000 \times (100 - T_{he}) = 1200 \times 30$

$T_{he} = 82^o$ C

$$\text{LMTD} = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)} = \frac{85-37}{\ln\left(\frac{85}{37}\right)} = \frac{48}{\ln\left(\frac{85}{37}\right)}$$

LMTD = 57.71^o C or K

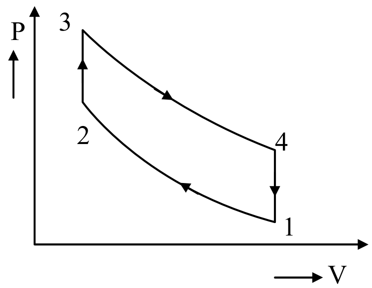
This is logarithmic mean temperature difference either we take in ^{o}C or we take in K the final answer will be 57.71 K (or) ^{o}C because it is a difference.

End of Solution

43. An air standard Otto cycle has thermal efficiency of 0.5 and the mean effective pressure of the cycle is 1000 kPa. For air assume specific heat ratio $\gamma = 1.4$ and specific gas constant R = 0.287 kJ/kg.K. If the pressure and temperature at the beginning of the compression stroke are 100 kPa and 300 K, respectively, then the specific net work output of the cycle is ______ kJ/kg (round off to two decimal places).

43. Ans: 708.77

Sol: Given:



$\eta_0 = 0.5$

$p_m = 100\,\text{kPa}$

$\gamma = 1.4$

R = 0.287 kJ/kg K

P_1 = 100 kPa

T_1 = 300 K

$$\eta_0 = 0.5 = 1 - \frac{1}{(r)^{\gamma-1}}$$

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

r = 5.656

At state (1)

$$P_1 v_1 = RT_1$$

$$100 v_1 = 0.287 \times 300$$

$$v_1 = 0.861 m^3/kg$$

$$r = \frac{v_1}{v_2}$$

$v_2 = 0.1522\ m^3/kg$

$$P_m = \frac{W_{net}}{v_1 - v_2}$$

$$1000 = \frac{W_{net}}{0.861 - 0.1522}$$

$$W_{net} = 708.77\ kJ/kg$$

44. Given a vector $\bar{u} = \frac{1}{3}\left(-y^3\hat{i} + x^3\hat{j} + z^3\hat{k}\right)$ and $\hat{n}$ as the unit normal vector to the surface of the hemisphere $(x^2 + y^2 + z^2 = 1;\ z \geq 0)$, the value of integral $\int(\nabla \times \bar{u}).\bar{u}\, dS$ evaluated on the curved surface of the hemisphere S is

(A) $-\frac{\pi}{2}$

(B) $\frac{\pi}{3}$

(C) $\frac{\pi}{2}$

(D) π

44. Ans: (C)

Sol: Given $\bar{u} = \frac{1}{3}(-y^3\bar{i} + x^3\bar{j} + z^3\bar{k})$

$$\Rightarrow \nabla \times u = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \frac{-y^3}{3} & \frac{x^2}{3} & \frac{z^3}{3} \end{vmatrix} = 0\bar{i} - 0\bar{j} + (x^2 + y^2)\bar{k}$$

Let $\phi = x^2 + y^2 + z^2 - 1 = 0$ be the equation of surface 'S'

Then $\bar{n} = \frac{\nabla\phi}{|\nabla\phi|} = \frac{2x\bar{i} + 2y\bar{j} + 2z\bar{k}}{\sqrt{(2x)^2 + (2y)^2 + (2z)^2}} = x\bar{i} + y\bar{j} + z\bar{k}$

$\Rightarrow (\nabla \times \bar{u}).\bar{n} = (x^2 + y^2)(z)$

Now, $\int((\nabla \times \bar{u}).\bar{n})ds = \int\int z(x^2 + y^2)ds$ ------ (1)

Let R be the projection of surface 's' on xy-plane

Then (1) becomes

$$\int_S (\nabla \times \bar{u})ds = \int\int_R (z(x^2 + y^2))\frac{dx\,dy}{|\bar{n}.\bar{k}|}$$

$$= \int\int_R (x^2 + y^2)dxdy, \text{ where R is } x^2+y^2=1$$

$$= \iint_R r^2 r\,dr\,d\theta \text{ , where } x = r\cos\theta,\ y = r\sin\theta,\ dx\,dy = r\,dr\,d\theta$$

$$= \int_{r=0}^{1} \int_{\theta=0}^{2\pi} r^3\,dr\,d\theta$$

$$= \left(\frac{r^4}{4}\right)_0^1 (\theta)_0^{2\pi} = \left(\frac{1}{4}\right)(2\pi)$$

$$\therefore \int_S ((\nabla \times \bar{n}).\bar{n})ds = \frac{\pi}{2}$$

Hence, option (C) is correct.

End of Solution

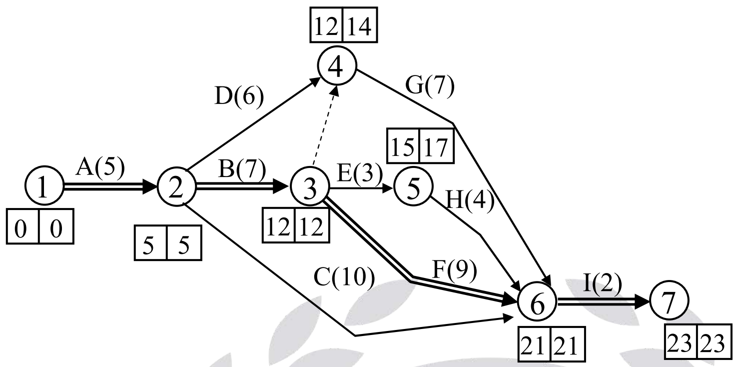
45. The activities of a project, their duration and the precedence relationships are given in the table. For example in a precedence relationship "X<Y,Z" means that X is predecessor of activities Y and Z. The time to complete the activities along the critical path is _______ weeks.

Activity	Duration (Weeks)	Precedence Relationship
A	5	A < B, C, D
B	7	B < E, F, G
C	10	C < I
D	6	D < G
E	3	E < H
F	9	F < I
G	7	G < I
H	4	H < 1
I	2	- - -

(A) 17
(B) 25
(C) 23
(D) 21

45. Ans: (C)

Sol:

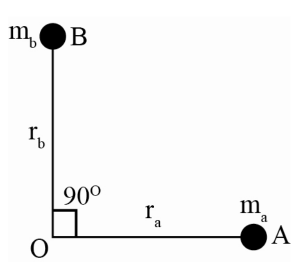


Path	Duration
A – D – G – I	20
A – B – Dummy – G – I	21
A – B – E – H – I	21
A – B – F – I	23
A – C – I	17

Critical path duration = 23 weeks

End of Solution

46. Two masses A and B having mass m_a and m_b respectively, lying in the plane of the figure shown, are rigidly attached to a shaft which revolves about an axis through O perpendicular to the plane of the figure. The radii of rotation of the masses m_a and m_b are r_a and r_b, respectively. The angle between lines OA and OB is 90°. If m_a = 10 kg, m_b = 20 kg, r_a = 200 mm and r_o = 400 mm, then the balance mass to be placed at a radius of 200 mm is _______ kg (round off to two decimal places).



46. Ans: 41.23

Sol: $m_A = 10$ kg

$m_B = 20$ kg

$r_A = 200$ mm

$r_B = 400$ mm

$r = 200$ mm

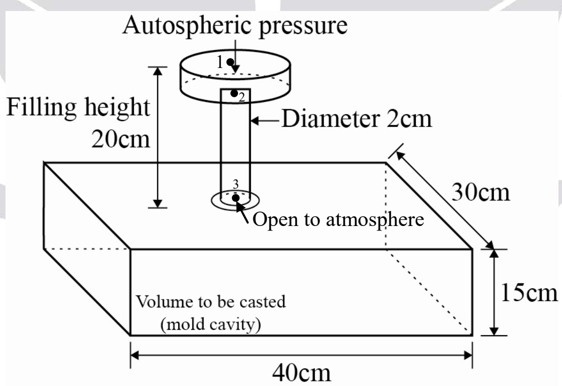
$$mr\omega^2 = \sqrt{(m_A r_A \omega^2)^2 + (m_B r_B \omega^2)^2}$$

$$\Rightarrow m \times 200 = \sqrt{(10\times200)^2 + (20\times400)^2}$$

$$\Rightarrow m = 41.23 \text{ kg}$$

End of Solution

47. The figure shows a pouring arrangement for casting of a metal block. Frictional losses are negligible. The acceleration due to gravity is 9.81 m/s^2. The time (in *s*, round off to two decimal places) to fill up the mold cavity (of size 40 cm × 30 cm × 15 cm) is ________



47. Ans: 28.92

Sol: $$\frac{\text{Volume}}{t} = A_c\sqrt{2gh_c}$$

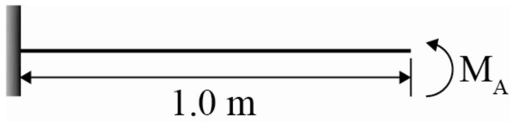
At point (3) is open to atmosphere so (3) is the choke.

$g = 9.81$ m/sec^2 = 981 cm/sec^2

$$\frac{40\times30\times15}{t} = \frac{\pi}{4}\times2^2\sqrt{2\times981\times20} \quad \Rightarrow \frac{18000}{t} = 622.32088$$

$$\Rightarrow t = 28.923 \text{ sec}$$

48. A horizontal cantilever beam of circular cross-section, length 1.0 m and flexural rigidity EI = 200 N.m^2 is subjected to an applied moment M_A = 1.0 N.m at the free end as shown in the figure. The magnitude of the vertical deflection of the free end is _______ mm (round off to decimal places).



48. Ans: 2.5

Sol: Deflection at free and $y_B = \frac{M_A L^2}{2EI}$

$$= \frac{1\times 1^2}{2\times 200} = 2.5\times 10^{-3}\,\text{m}$$

$\therefore\ y_B = 2.5\times 10^{-3}\times 10^{3}$ mm = 2.5 mm

$\therefore\ y_B = 2.5$ mm

End of Solution

49. Water flows through two different pipes **A** and **B** of the same circular cross-section but at different flow rates. The length of pipe **A** is 1.0 m and that of pipe **B** is 2.0 m. The flow in both the pipes is laminar and fully developed. If the frictional head loss across the length of the pipes is same the ratio of volume flow rates Q_B/Q_A is _______ (round off to decimal places).

49. Ans: 0.50

Sol: Given data,

Water is flowing in two different pipes A and B.

Pipe	Area	Flow rate	Length	Head loss due to friction
A	A_A	Q_A	$L_A = 1$ m	h_{fA}
B	A_B	Q_B	$L_B = 2$ m	h_{fB}

Given that, $A_A = A_B \Rightarrow d_A = d_B$

Flow is laminar in both pipes.

In laminar flow,

$$\Delta P = \frac{32\mu VL}{d^2} = \frac{128\mu LQ}{\pi d^4}$$

and $h_f = \frac{\Delta P}{\rho g} = \frac{128\mu LQ}{\rho\pi g d^4}$

Since, μ, π, g and ρ are all same for both pipes, we can write

$h_f \propto L\,Q$ (as d is same)

or $\frac{h_{fA}}{h_{fB}} = \frac{L_A}{L_B} \times \frac{Q_A}{Q_B}$

since, $h_{fA} = h_{fB}$

$$\frac{Q_B}{Q_A} = \frac{L_A}{L_B} = \frac{1}{2} = 0.50$$

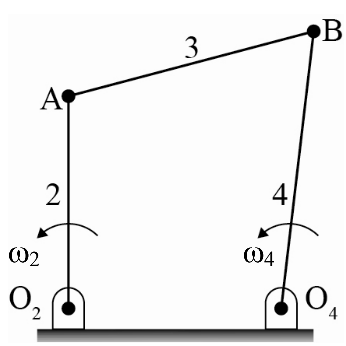
End of Solution

50. A four bar mechanism is shown in the figure. The link numbers are mentioned near the links. Input link 2 is rotating anticlockwise with a constant angular speed ω_2. Length different links are:

$O_2O_4 = O_2A = L$,

$AB = O_4B = \sqrt{2}L$,

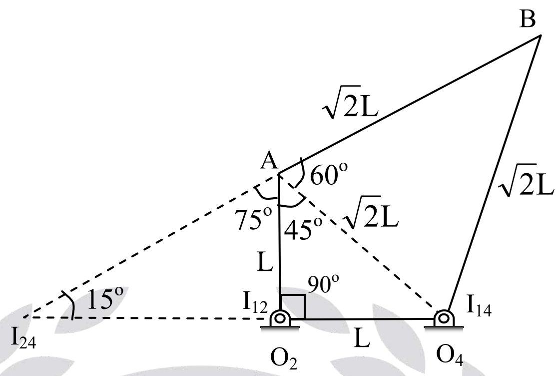
The magnitude of the angular speed of the output link 4 is ω_4 at the instant when link 2 makes an angle of 90° with O_2O_4 as shown. The ratio $\frac{\omega_4}{\omega_2}$ is _______ (round off to two decimal places).



50. Ans: 0.789

Sol: $O_2A = O_2O_4 = L$

$AB = O_4B = L\sqrt{2}$



$\omega_2 I_{12}I_{24} = \omega_4 I_{14}I_{24}$

$$\frac{\omega_4}{\omega_2} = \frac{I_{12}I_{24}}{I_{14}I_{24}}$$

from triangle O_2AI_{24},

$$\frac{I_{12}I_{24}}{\sin 75} = \frac{L}{\sin 15}$$

$$I_{12}I_{24} = L\frac{\sin 75}{\sin 15} = 3.73L$$

$I_{14}I_{24} = 3.73L + L = 4.73L$

$$\frac{\omega_4}{\omega_2} = \frac{I_{12}I_{24}}{I_{14}I_{24}} = \frac{3.73L}{4.73L} = 0.789$$

End of Solution

51. An idealized centrifugal pump (blade outer radius of 50 mm) consumes 2 kW power while running at 3000 rpm. The entry of the liquid into the pump is axial and exit from the pump is radial with respect to impeller. If the losses are neglected, then the mass flow rate of the liquid through the pump is _____ kg/s (round off to two decimal places).

51. Ans: 8.11

Sol: The theoretical head (Euler's head) is given by

$$H_e = \frac{u_2 V_{w2}}{g}$$

$$= \frac{u_2^2}{g} \quad \text{as } (V_{w2} = u_2 \text{ for radial exit})$$

Thus,

$P_{th} = \rho g\, Q\, H_e$

$$= \rho g Q \times \frac{u_2^2}{g}$$

$$= \rho Q u_2^2$$

$$P_{th} = \dot{m} u_2^2$$

or,

$$\dot{m} = \frac{P_{th}}{u_2^2}$$

where, $u_2 = \frac{\pi d_2 N}{60} = \pi \times 0.1 \times \frac{3000}{60} = 5\pi \text{ m/s}$

Hence, $\dot{m} = \frac{2\times10^3}{(5\pi)^2} = 8.11 \text{kg/s}$

End of Solution

52. In an orthogonal machining with a single point cutting tool of rake angle 10°, the uncut chip thickness and the chip thickness are 0.125 mm and 0.22 mm respectively. Using Merchant's first solution for the condition of minimum cutting force the coefficient of friction at the chip-tool interface is _______ (round off to two decimal places).

52. Ans: 0.737

Sol: $\alpha = 10^0, t_1 = 0.125, \quad t_2 = 0.22$

$$r = \frac{0.125}{0.22} = 0.57$$

$$shear\ angle,\ \phi = tan^{-1}\left[\frac{r\cos\alpha_0}{1 - r\sin\alpha_0}\right]$$

$$\phi = tan^{-1}\left[\frac{0.57\cos 10}{1 - 0.57\sin 10}\right]$$

$$\phi = 31.8$$

From Merchant's 1^{st} *solution*

$$2\phi + \beta - \alpha_0 = 90$$

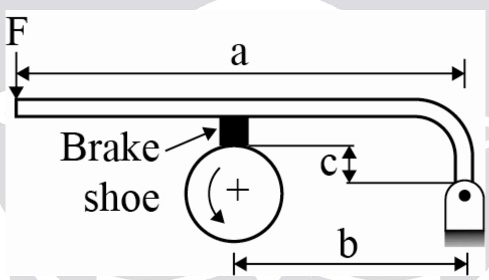
$$\beta = 90 + \alpha_0 - 2\phi \;= 90 + 10 - 2 \times 31.8$$

$$= 36.4^0$$

Coefficient of friction, $\mu = \tan\beta = \tan 36.4 = 0.737$

End of Solution

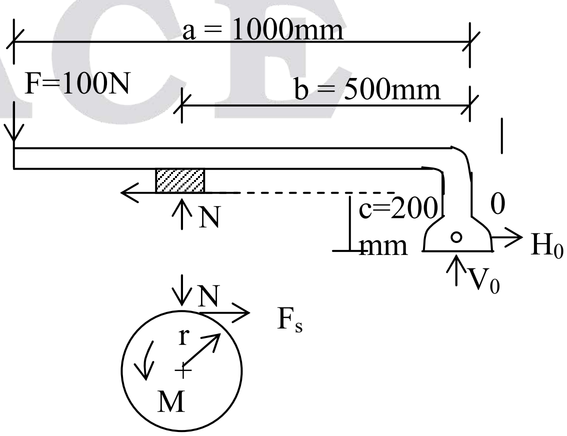
53. A short shoe external drum brake is shown in the figure. The diameter of the brake drum is 500 mm. The dimensions a = 1000 mm, b = 500 mm and c = 200 mm. The coefficient of friction between the drum and the shoe is 0.35. The force applied on the lever F = 100 N as shown in the figure. The drum is rotating anti-clockwise. The braking torque on the drum is ______ N-m (round off to two decimal places).



53. Ans: 20.35

Sol: W.r.t FBD of link

$F_s = \mu_s N = 0.35 \times N$;



Taking summation of moment about O = zero

$\Sigma M_O = 0$

$N \times 500 - F_s \times 200 - F \times 1000 = 0$

$N \times 500 - 0.35 \times N \times 200 - 100 \times 1000 = D$

$$N = \frac{100 \times 1000}{(500 - 70)} = 232.558 N$$

With respect to FBD of drum

Braking torque $M = F_s \times r = \frac{0.35 \times 232.558 \times 500}{2 \times 1000}$

$M = 20.35$ N - m

End of Solution

54. The thickness of a sheet is reduced by rolling (without any change in width) using 600 mm diameter rolls. Neglect elastic deflection of the rolls and assume that the coefficient of friction at the roll-workpiece interface is 0.05. The sheet enters that rotating rolls unaided. If the initial sheet thickness is 2 mm, the minimum possible final thickness that can be produced by this process in a single pass is _______ mm (round off to two decimal places).

54. Ans: 1.25

Sol: $(\Delta h)_{max} = \mu^2 R$

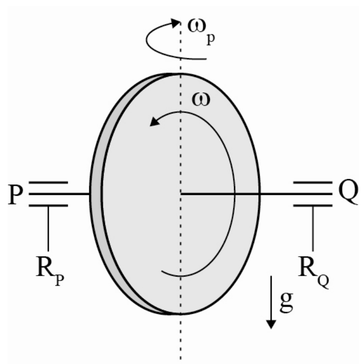
$\mu = 0.05$, $R = 300$ mm

$(\Delta h)_{max} = 0.05^2 \times 300 = 0.75$ mm

Minimum possible final thickness $= h_0 - (\Delta h)_{max}$

$= 2 - 0.75 = 1.25$ mm

55. A uniform disc with radius *r* and a mass of *m* kg is mounted centrally on a horizontal axle of negligible mass and length of 1.5 *r*. The disc spins counter-clockwise about the axle with angular speed ω, when viewed from the right-hand side bearing, Q. The axle precesses about a vertical axis at $\omega_p = \omega / 10$ in the clockwise direction when viewed from above. Let R_P and R_Q (positive upwards) be the resultant reaction forces due to the mass and the gyroscopic effect, at bearings P and Q, respectively. Assuming $\omega^2 r = 300$ m/s^2 and g = 100 m/s^2, the ratio of the larger to the smaller bearing reaction force (considering appropriate signs) is ________.



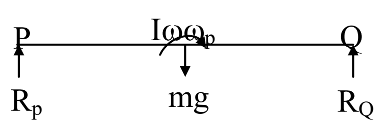
55. Ans: –3

Sol: Given:

$$\omega_p = \frac{\omega}{10}$$

$$\omega^2 = 300 \text{ m/s}^2$$

$$g = 10 \text{ m/s}^2$$



$$\sum F_y = 0 \Rightarrow R_p + R_Q = mg \text{ ------(1)}$$

$$\Rightarrow R_Q(1.5r) = (mg \times 1.5)\frac{r}{2} + I\omega.\omega_p$$

$$\Rightarrow (1.5r)R_Q = mg \times \frac{1.5r}{2} + \frac{mr^2}{2}\frac{\omega^2}{10}$$

$$\Rightarrow (1.5R)R_Q = mg \times \frac{1.5r}{2} + \frac{m}{2}\frac{(r\omega^2)r}{10}$$

$$\Rightarrow 1.5R_Q = \frac{1.5\,mg}{2} + \frac{m}{2} \times \frac{300}{10}$$

$$\Rightarrow R_Q = 15\,m \text{-------(ii)}$$

From equation (i) and (ii)

$R_P + 15m = 10m$

$R_p = -5$ m

$$\Rightarrow \frac{R_{larger}}{R_{smaller}} = \frac{R_Q}{R_P} = \frac{15\,m}{-5\,m} = -3$$

End of Solution