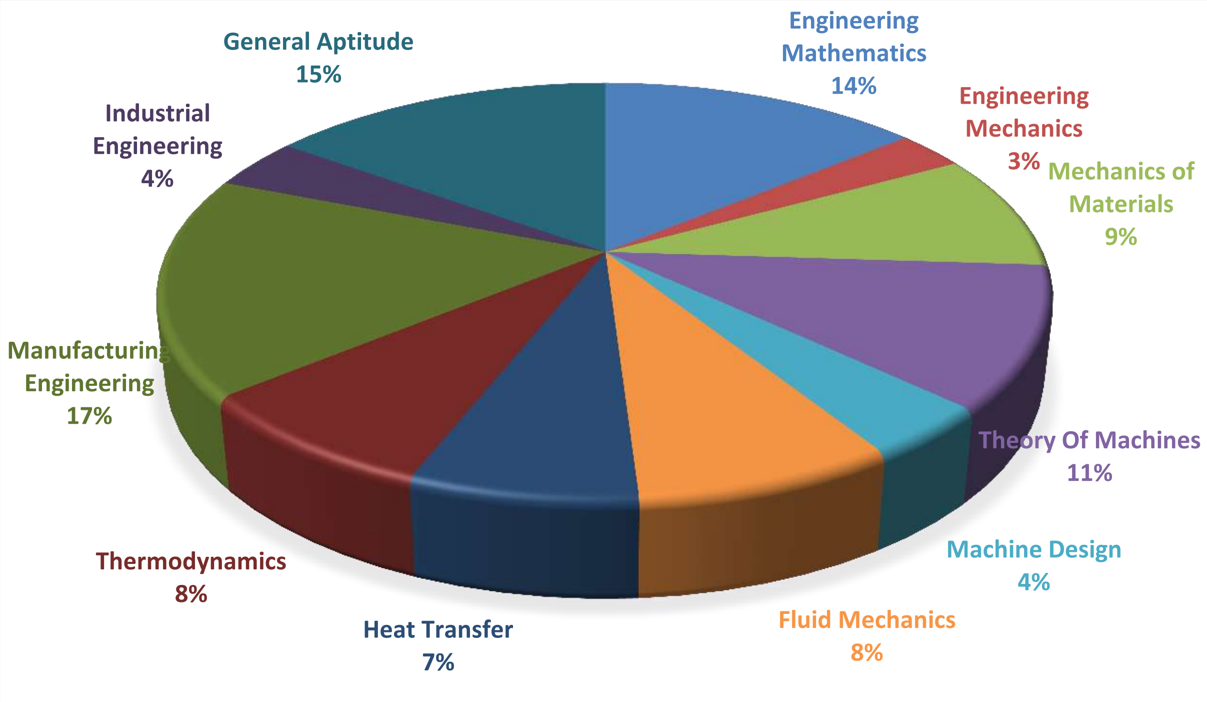
ANALYSIS OF GATE 2019

Mechanical Engineering



ME ANALYSIS-2019_2-Feb_Afternoon

SUBJECT	No. of Ques.	Topics Asked in Paper(Memory Based)	Level of Ques.	Total Marks
Engineering Mathematics	1 Marks: 6 2 Marks: 4	Differential equation, Statistics, Vector Calculus, Complex variable, Linear algebra, Probability, Numerical methods	Medium	14
Engineering Mechanics	1 Marks: 1 2 Marks: 1	Trusses and frames, Collision, Friction	Medium	3
Mechanics of Materials	1 Marks: 3 2 Marks: 3	Cylinder, Analysis of Stress and Strain, Deflection	Medium	9
Theory Of Machines	1 Marks: 1 2 Marks: 5	Vibration, Gyroscope, Velocity Analysis, Balancing, Four bar Mechanism	Medium	11
Machine Design	1 Marks: 2 2 Marks: 1	Gear, Fatigue Design, Brakes, Spur gear	Medium	4
Fluid Mechanics	1 Marks: 2 2 Marks: 3	Fluid kinematics, Reynolds Number, Friction Loss, Pumps	Tough	8
Heat Transfer	1 Marks:3 2 Marks: 2	LMTD, Convection, Heat Conduction, Shape factor	Tough	7
Thermodynamics	1 Marks: 2 2 Marks: 3	Otto Cycle, Heat Pump Cycle, Irreversibility	Medium	8
Manufacturing Engineering	1 Marks: 5 2 Marks: 6	Merchant Circle, Rolling , Face Diagram	Tough	17
Industrial Engineering	1 Marks: 0 2 Marks: 2	Pert – CPM, Inventory Control	Medium	4
General Aptitude	1 Marks: 5 2 Marks: 5	Pipes and Cisterns ,Coding and Decoding, Percentage , Grammar-Vocabulary ,Data Interpretation	Medium	15
Total	65			100
Faculty Feedback	The second paper was comparatively hard. Except for SOM, mostly the other subjects had a level above the morning session. In fact compare to previous year also the paper was tougher.			

GATE 2019 Examination

Mechanical Engineering

Test Date: 2-FEB-2019

Test Time: 2.30 PM to 5:30 PM

Subject Name: Mechanical Engineering

General Aptitude

Q.1 - Q.5 Carry One Mark each.

1. Once the team of analysts 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) Will be
   (B) Were to be
   (C) Are going to be
   (D) Might be
   [Ans. B]
   Since the 1st clause is in present tense, the second clause will not use past tense. are going to be, will be, might be fill the given blank appropriately.

2. A final examination is the ________ of a series of evaluations that a student has to go through.
   (A) Culmination
   (B) Desperation
   (C) Insinuation
   (D) Consultation
   [Ans. A]
   Desperation: a state of despair, distress or hopelessness
   Insinuation: an unpleasant hint or suggestion of something bad
   Consultation: the act of formally consulting
   Culmination: highest point of something that attained after a long time.

3. Are these enough seats here? There are ________ people here than I expected.
   (A) Least
   (B) Many
   (C) Most
   (D) More
   [Ans. D]

More is used in case of countable nouns and is a comparative term.

4. If IMHO=JNIP; IDK=JEL; and SO=TP, then IDC = ________.
(A) JDE
(B) JED
(C) JCD
(D) JDC
[Ans. B]
I+1=J, M+1=N, H+1=I and O+1=P
And similarly for all other analogies.
So, IDC=(I+1)+(D+1)+(C+1)=JED

5. 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) 7
(C) 6
(D) 8
[Ans. B]
XYZ=192 and Z=4
$\therefore XY = \frac{192}{4} = 48$
Possible values of X, Y are (48,1), (2, 24), (3, 16), (4, 12), (6, 8)
Since, $P = \frac{X+Y}{2}$
so, for P_{min}, we shouild have $(X+Y)_{min}$, which is possible in $(6, 8)$
$\therefore P_{min} = \frac{6+8}{2} = 7$

Q.6 - Q.10 Carry Two Mark each.

6. 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-colonized 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 stories set in foreign places
(B) None of the students had written stories set in India
(C) Some of the students had written about ice cubes and cowboys
(D) None of the students had written about ice cubes and cowboys

[Ans. B]

None of the students had written stories set in India. It is explicitly stated that the writer was surprised at receiving stories from the studentsthat were all set in distant places.

7. X is an online media provider. By offering unlimited and exclusive online content at attractive prices for a loyalty membership, X is almost forcing its customers towards it 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) Most households that subscribe to X's loyalty membership discontinue watching cable television
(B) Cable television operators don't subscribe to X's loyalty membership
(C) The X is cancelling accounts of non-members
(D) Non –members prefer to watch cable television

[Ans. A]

Most households that subscribe to X's loyalty membership discontinue watching cable television. It is estimated that if X continues to offer loyalty membership, the number of subscribers of X will outgrow that of cable television. It is based on the assumption that most of the households subscribing to X don't watch cable television any longer.

8. 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) 10.00
(C) 35.70
(D) 25.00

[Ans. A]

Assume in 2015, GDP was x

So, in 2016, GDP would be 1.1x

Fiscal deficit in 2015 $= \frac{4x}{100}$

And fiscal deficit in 2016 $= \frac{5}{100}(1.1x)$

$\therefore$ actual % increase in Fiscal deficit $= \dfrac{\left(\frac{5.5x}{100} - \frac{4x}{100}\right)}{\frac{4x}{100}} * 100 = \dfrac{1.5}{4} * 100 = 37.5\%$

9. Two pipes P and Q can fill a tank in 6 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) 13.50
(B) 14.50
(C) 15.50
(D) 16.50

[Ans. B]

Given: P alone can fill the tank in 6 hours
So, in 1 hour, part of tank filled by P alone is 1/6th
Given: Q alone can fill the tank in 9 hours
So, in 1 hour, part of tank filled by Q alone is 1/9th
Given: R can empty the tank in 12 hours
So, in 1 hour, part of tank emptied by R is 1/12th
Initially, P and R are opened for 4 hours.

So, part of tank filled $= 4\left(\frac{1}{6} - \frac{1}{12}\right) = \frac{1}{3}$

After 4 hours, P is closed and For 6 more hours Q and R are opened.

So, part of tank filled $= 6\left(\frac{1}{9} - \frac{1}{12}\right) = \frac{1}{6}$

So, total tank filled in 10 hours $= \frac{1}{3} + \frac{1}{6} = \frac{1}{2}$

According to question, remaining ½ part of the tank is filled by Q alone.
As Q takes 9 hours to fill the tank completely, so it will take 4.5 hours to fill remaining half of the tank.
So, total time taken=(4 + 6 + 4.5) hours= 14.5 hours

10. 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 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) 16.24

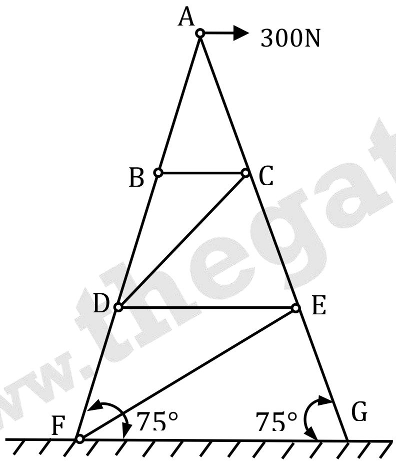
(B) 23.97
(C) 25.86
(D) 38.74
[Ans. B]
Revenue shared by Pool= 170+ 320+215+190 = 895
Revenue shared by Mini= 110+ 220+180+70 = 580
Revenue shared by Prime= 75+ 180+120+90 = 465
So, total revenue generated by Mola= 895+580+465 = 1940

$\therefore$ Percentage share of revenue contributed by Prime $= \dfrac{465}{1940} = 23.97\%$

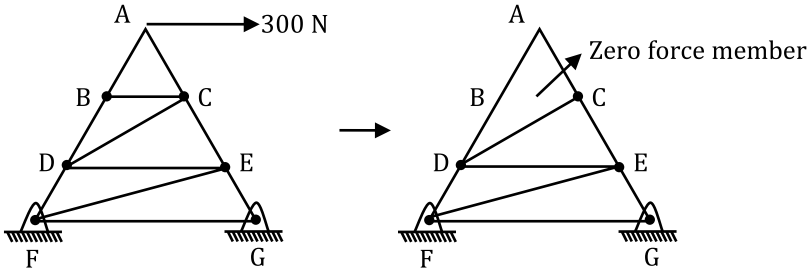
Technical

Q.1 - Q.25 Carry One Mark each.

1. 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.



[Ans. 0]



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

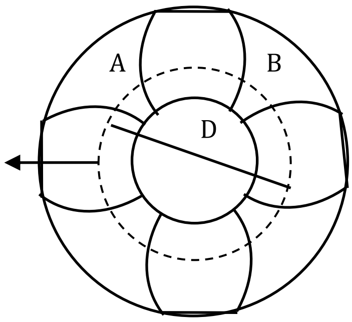
(A) $\frac{\pi D}{T}$

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

(C) $\frac{T}{D}$

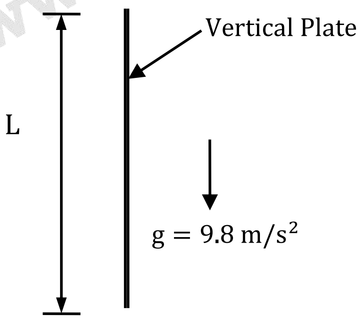
(D) $\frac{D}{T}$

[Ans. A]



Circular pitch $(P_c) = \frac{\pi D}{T}$

3. A thin vertical flat plate of height L, and infinite width perpendicular to 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 give as $Nu - K\,Ra^{1/4}$ where K is a constant. The length scales for Nusselt and Rayleigh numbers are the height of the plate. The height of the plate is increased to 16L keeping all other factors constant.



If the average heat transfer coefficient for the first plate is h_1 and that for the second plate is h_2 the value of the ration h_1/h_2 is ________.

[Ans. *]Range 2 to 2

$N_u = h\, l_c$

$$\text{Or } h = \frac{N_u k}{l_c}$$

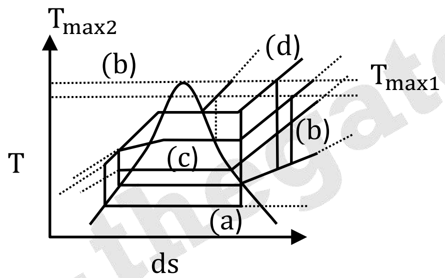
$$h \propto \frac{l_c^{\left(\frac{3}{4}\right)}}{l_c}$$

$$h \propto l_c^{\left(\frac{-1}{4}\right)}$$

$$\frac{h_1}{h_2} = \frac{l_{c1}^{\left(\frac{-1}{4}\right)}}{l_{c2}^{\left(\frac{-1}{4}\right)}}$$

$$= \left[\frac{l_{c2}}{l_{c1}}\right]^{1/4} = 2$$

4. 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) Decreasing the boiler pressure
(C) Increasing the turbine inlet temperature
(D) Decreasing the condenser pressure
[Ans. C]



Decreasing the condenser pressure will increase efficiency but increase the moisture content of stream at turbine outlet, decreasing the boiler pressure will decrease the mean temperature of heat addition and reduce efficiency. Increasing the boiler pressure will increase efficiency but also increase moisture at outlet. Increasing the inlet temperature of turbine will increase mean temperature of heat addition and reduce moisture content.

5. The fluidity of molten metal of cast alloys (without any addition of fluxes) increases with increase in
(A) Freezing range
(B) Viscosity
(C) Surface tension
(D) Degree of superheat
[Ans. D]
Fluidity:

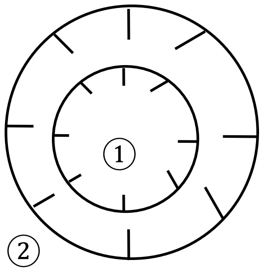
• The ability of a metal of flow and fill a mold is known as fluidity. Pouring temperature:
• The most important controlling factor of fluidity is the pouring temperature or the amount of superheat.
• Higher the pouring temperature, higher the fluidity.

6. Endurance limit of a beam subjected to pure bending decreases with
(A) Increase in the surface roughness and decrease in the size of the beam
(B) Decrease in the surface roughness and increase in the size of the beam
(C) Increase in the surface roughness and increase in the size of the beam
(D) Decrease in the surface roughness and decrease in the size of the beam
[Ans. C]
Increase in surface roughness & increase in size of beam

7. Hardenability of steel is a measure of
(A) The ability to harden when it is cold worked
(B) The ability to retain its hardness when it is heated to elevated temperatures
(C) The depth to which required hardening is obtained when it is austenitized and then quenched
(D) The maximum hardness that can be obtained when it is austenitized and then quenched
[Ans. C]
The depth and hardness achieved by quenching is called hardenability. Hardenability should not be confused with hardness. Hardenability can be defined as the depth to which a certain hardness level can be obtained by the quenching process.

8. 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 ________
[Ans. *]Range 1 to 1
$E = 0.5\, V_d^2\, C$
$= 0.5 \times 200^2 \times 50 \times 10^{-6} = 1J$

9. Sphere 1 with a diameter of 0.1m is completely enclosed by another sphere 2 of diameter 0.4 m. the view factor F_{12} is ________
(A) 0.0625
(B) 0.5
(C) 0.25
(D) 1.0
[Ans. D]



For ①

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

But $F_{11} = 0$

$F_{12} = 1$

10. 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) $\left(\frac{\partial P}{\partial V}\right)_T$

(C) $-\left(\frac{\partial T}{\partial V}\right)_P$

(D) $\left(\frac{\partial T}{\partial P}\right)_S$

[Ans. D]

$$\left(\frac{\partial V}{\partial S}\right)_P = \left(\frac{\partial T}{\partial P}\right)_S$$

11. 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 v=0.3 are given. The principal strains in the plane of the sheet are

(A) (0.35, – 0.15)

(B) (0.5, –0.5)

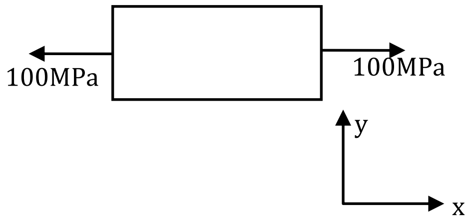
(C) (0.5, – 0.15)

(D) (0.5, 0.0)

[Ans. C]

$\sigma_x = 100\text{MPa}$

$\sigma_x = 0$



$\epsilon_x = \frac{\sigma_x}{E} = \frac{100}{200} = 0.5$

$\epsilon_y = -\mu\, \epsilon_x = -0.3 \times 0.5 = -0.15$

12. A write of circular cross-section of diameter 1.0 mm is bent into a circular are 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.

[Ans. *]Range 49 to 51

Since pure bending

Bending equation – $\frac{(\sigma_b)_{max}}{y_{max}} = \frac{E}{R}$

$(\sigma_b)_{max} = \frac{100 \times 10^3}{R} \times (d/2)$

$(\sigma_b)_{max} = \frac{10^5 \times 1}{2 \times 10^3} = 50\text{MPa(Tensile)}$

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

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

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

(C) $\begin{matrix} 0 & 1 \\ 1 & 0 \end{matrix}$

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

[Ans. C]

$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$

$x = y; y = x$

14. 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 $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$

[Ans. B]

C–R equation for the, f(z) = u + iv to be analytic are $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$

15. 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) Quadratic

(B) Linear

(C) Logarithmic

(D) Exponential

[Ans. C]

$$\frac{\partial^2 T}{\partial x^2} + \frac{\dot{q}g}{k} = \frac{\rho C}{k}\frac{\partial T}{\partial t}$$

$$\frac{d^2 T}{dx^2} = 0$$

$$\frac{d}{dx}\left(A\frac{dT}{dx}\right) = 0$$

$$A\frac{dT}{dx}dT = C$$

$$\frac{dT}{dx} = \frac{C}{A}$$

$$\frac{dT}{dx} = \frac{C}{ax + b}$$

Given that area is a linear function of x

$$dT = \frac{C}{(ax + b)}\,dx$$

So the temperature profile will be logarithmic

16. 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 eigenvalues of matrix [A] is

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

[Ans. D]

$Ax = R$

$Ax = \lambda x$

$$[A] = \begin{bmatrix} 2 \\ 1 \\ 4 \end{bmatrix} = 16 \begin{bmatrix} 2 \\ 1 \\ 4 \end{bmatrix}$$

$\lambda = 16$

17. 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) $y = e^{-4x} + 5$
(D) $y = e^{-4x} + 1.25$

[Ans. B]

$$\frac{dy}{dx} + Py = Q$$

$$IF = \int_e P\,dx$$

$$= \int_e 4\,dx = e^{4x}$$

$$y(IF) = \int (IF)Q\,dx$$

$$ye^{4x} = \int e^{4x} 5\,dx$$

$$ye^{4x} = \int 5\frac{e^{4x}}{4} + C$$

$$y = \frac{5}{4} + Ce^{-4x}$$

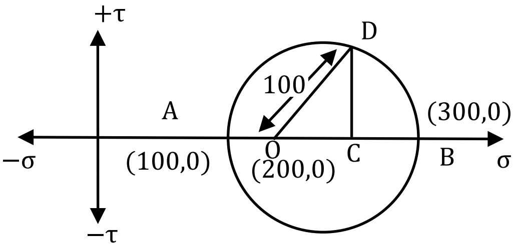
$$y(0) = \frac{5}{4} + Ce^{-4(0)} = 2.25$$

C=1

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

18. 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.

[Ans. *]Range 79 to 81



Principal stresses

$(\sigma_1) = 300\text{MPa}$

$(\sigma_2) = 100\text{MPa}$

$\text{OC} = 60\text{Mpa}$

$\text{CD} = \sqrt{100^2 - 60^2}$

$\tau = 80$ MPa → shear stress on that plate

19. A two-dimensional incompressible frictionless flow field is given by $\vec{u} = x\hat{i} - y\hat{j}$. 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) $-\rho(x^2\hat{i} + y^2\hat{j})$

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

[Ans. B]

$$-\frac{1}{\rho}\vec{\nabla}p - gj = \vec{a}$$

$$\frac{\partial P}{\partial x} = -Ja_x\vec{i}$$

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

$$a_x = x + (-y) \times 0$$

$$\Rightarrow a_x = x$$

$$\text{Thus}\frac{\partial p}{\partial x} = -\rho x$$

$$\frac{\partial P}{\partial y} = -Ja_y$$

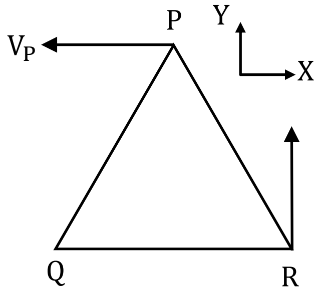
$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}$$

$a_y = x \times \theta + (-y) \times (-1)$
$\Rightarrow a_y = y$
Thus $\frac{\partial p}{\partial y} = -\rho_y$
$\frac{\partial P}{\partial x}\vec{i} + \frac{\partial P}{\partial x}\vec{j}$
$-\rho_x\vec{i} + (-\rho_y)\vec{j}$
$-\rho(x\vec{i} + y\vec{j})$

20. Water enters a circular pipe of length L= 5.0 m and diameter D=0.20 m with Reynolds 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 ________.
[Ans. *]Range 500 to 500
Re=$\frac{\rho VD}{\mu}$ for pipe flow
V = mean velocity
Exit mean velocity V2
$\dot{m}_{in} = \dot{m}_{out}$
$\rho A_1 V_1 = \rho A_2 V_2$
{∵ Water is incompressible fluid, so density will remain same}
Given $A_1 = A_2$
$\because V_1 = V_2$
So, Reynolds number is constant i.e. 500 at exit.

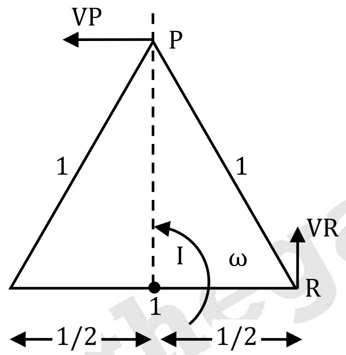
21. The most common limit gage used for inspecting the hole diameter is
(A) Master gage
(B) Ring gage
(C) Plug gage
(D) Snap gage
[Ans. C]

22. 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) $2V_R$
(B) $2V_P$
(C) $V_R/\sqrt{3}$
(D) $V_P/\sqrt{3}$

[Ans. A]



Let ω is the angular velocity of the Rigid body PQR. Body PQR will be in pure rotation about it's instantaneous centre

Velocity of point R $= IR \times \omega$

(i. e. V_R)

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

23. 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) Strip rolling
(B) Roll forming
(C) Knurling
(D) Chamfering

[Ans. C]

24. If x is the mean of data 3, x, 2 and 4, then the mode is________.

[Ans. *]Range 3 to 3

$\text{Mean} = \dfrac{3 + x + 2 + 4}{4} = x$

$9 + x = 4x$

$3x = 9$

$x = 3$

25. 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) $\sqrt{2}$

(B) $4\sqrt{2}$

(C) $2\sqrt{2}$

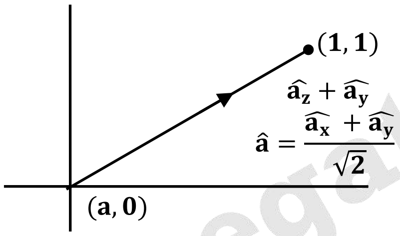
(D) $\sqrt{2}$

[Ans. C]

$\text{Directional derivative} = \nabla f . \hat{a}$

$\nabla f = 2x\, \hat{a}_x + 2y\, \hat{a}_y$

$\nabla f|_{(1,1)} = 2\, \hat{a}_x + 2\, \hat{a}_y$

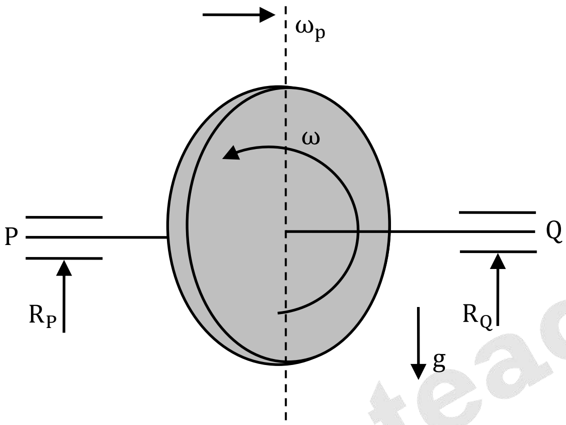


$DD = (2\, \hat{a}_x + 2\, \hat{a}_y)$

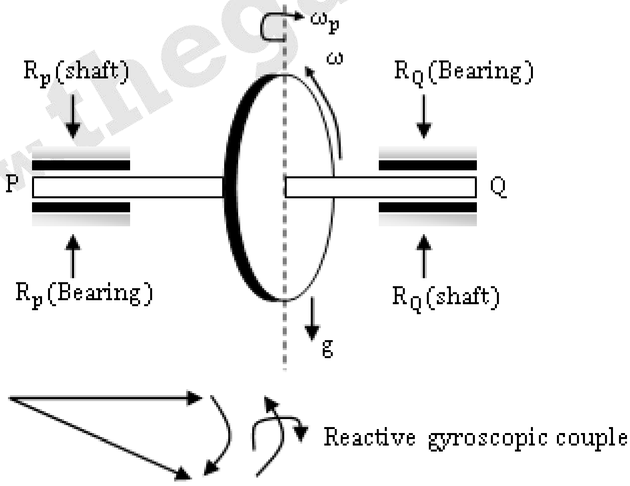
$= \left(\dfrac{\hat{a}_x + \hat{a}_y}{\sqrt{2}}\right) = \dfrac{2 + 2}{\sqrt{2}} = 2\sqrt{2}$

Q.26 - Q.55 Carry Two Mark each.

26. A uniform disc with r and a mass of m kg is mounted centrally on a horizontal axle of negligible mass and length of 1.5r. The disc spins counter-clock wise about the axle with angular speed ω, when viewed from the right-hand side bearing Q. The axle processes 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 $g = 10 m/s^2$, the ratio of the larger to the smaller bearing reaction force (considering appropriate signs) is ____________



[Ans. *] Range: -3 to -3



Active gyroscopic couple $= \omega\omega_p$

$$= \frac{m^2}{2} \times \omega \times \frac{\omega}{10} = \left(\frac{m\omega^2 r^2}{20}\right)$$

Reaction force at bearing P due to gyroscopic couple is (R_{p_m})

$$R_{P_m} = \frac{m\omega^2 r^2}{20 \times 1.5r}$$
$$= \frac{m\omega^2 r^2}{20 \times 1.5r} = \frac{m\omega^2 r}{30} = 10m\text{ N (upward)}$$

Reaction force at bearing Q due to gyroscopic couple is (R_{Q_m})

$$R_{Q_m} = \frac{m\omega^2 r^2}{20 \times 1.5r} = \frac{m\omega^2 r}{30} = 10m\text{ N(download)}$$

Reaction force at bearing P due to gravity $= \frac{mg}{2}$ (downward)

=5mN

Reaction force at bearing Q due to gravity $= \frac{mg}{2} = 5\text{mN(upward)}$

Reaction at bearing P, $R_P = 10\text{ mN} - 5\text{mN} = 5\text{mN (upward)}$

Reaction at bearing Q, $R_Q = -10\text{ mN} - 5\text{mN} = -15\text{mN (upward)}$

$$\frac{R_Q}{R_P} = -\frac{15}{5} = -3$$

27. 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 two decimal places).

[Ans. *] Range: 0.16 to 0.18

Binomial distribution

$p = 0.05; q = 1 - 0.05 = 0.95; n = 15$

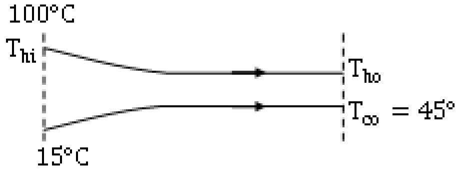
$1 - p(0) - p(1)$

$1 - {}^{15}C_0\, p^0 q^{15} - {}^{15}C_1 p^1\, q^{14}$

$= 1 - (0.95)^{15} - 15(0.05)(0.95)^{14} = 0.1709$

28. 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 $C_h = 2000\text{W/K}$ and $C_c = 1200\text{W/K}$ 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).

[Ans. *]Range 57.00 to 58.00



$C_h = 2000\text{ W/K}$

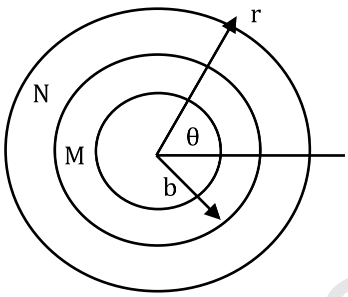
$C_c = 1200\text{ W/K}$

By energy equation,

$C_h(\Delta T_h) = C_c(\Delta T_c)$

$2000\,(100 - T_{ho}) = 1200(30)$
$T_{ho} = 82°C$
$$\text{LMTD} = \frac{((100-15)-82-45)}{\ln\left(\frac{100-15}{82-45}\right)} = 57.71°C$$
Since LMTD is temperature difference so the answer will be 57.71 K

29. 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 (u_r^M, u_θ^M) and $\sigma_{rr}^M, \sigma_{\theta\theta}^M)$ denote the radial and tangential displacement and stress components respectively in material M. Similarly (u_r^N, u_θ^N) and $\sigma_{rr}^N, \sigma_{\theta\theta}^N)$ 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:



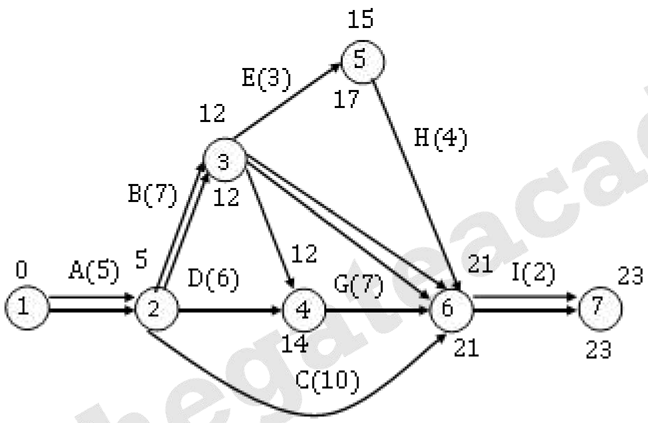
(A) $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$ only
(B) $\sigma_{rr}^M = \sigma_{rr}^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only
(C) $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only
(D) $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$ and $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$
[Ans. A]
Due to fluid pressure both the cylinder will remain in contact, so radial displacement and radial stress will be same at interface. But due to frictionless surface both the cylinder can slip tangentially, therefore tangential displacement and tangential stress will be different.

30. 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<I
I	2	---

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

[Ans. C]



So critical path is A − B − F − I
Critical path duration = 23 weeks

31. 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 to two decimal places).

[Ans. *]Range 941.0 to 946.0

D=10,000 units

Ordering quantity= 400 /order=Q

$C_C = C_n = \text{Rs. } 24/\text{unit/yr}$

$C_o = \text{Rs. } 400/\text{Order}$

$$T'_{C=400} = \frac{Q}{2} \times C_C + \frac{D}{2} \times C_0$$

$$= \frac{400}{2} \times 24 + \frac{10{,}000}{400} \times 400 = 14{,}800$$

$$T_C = \sqrt{2.C_0.D_{Cc}} = \sqrt{2 \times 400 \times 10{,}000 \times 24} = 13856.4$$

$$T'_C - T_C = 943.6 \text{ Rs}$$

32. 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 44km/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).

[Ans. *]Range 21.90 to 22.10

Case-1: $C_{D1} = 0.1$

$U_{\infty 1} = 44$ km/h

Case-2: $C_{D2} = 0.8$

$U_{\infty 2} = ?$

As we know, Power, $P = C_D \times \frac{1}{2}\rho U_\infty^3 \times A$

For same power, density and frontal area,

(power)1 = (power)2

$$C_{D1}\frac{1}{2}\rho_1 A_1 U_{\infty 1}^3 = C_{D2}\frac{1}{2}\rho_2 A_2 U_{\infty 2}^3$$

$$U_\infty^3 \propto \frac{1}{C_D}$$

$$\Rightarrow \left(\frac{U_{\infty 2}}{U_{\infty 1}}\right)^3 = \frac{C_{D1}}{C_{D2}}$$

$$\left(\frac{U_{\infty 2}}{44}\right)^3 = \frac{0.1}{0.8}$$

$$U_{\infty 2} = \frac{44}{2} = 22 \text{ km/h}$$

33. A ball of mass 3kg moving with a velocity of 4m/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 3kg ball is 6J. The possible value(s) of m is/are:

(A) 1kg, 6kg

(B) 1kg only

(C) 6kg only

(D) 1kg, 9kg

[Ans. D]

$\frac{1}{2} m_1 v_1^2 = 6$

$\frac{1}{2} \times 3 \times v_1^2 = 6$

$v_1^2 = 4$

$v_1 = \pm 2$

Case I

From conservation of momentum

$3 \times 4 + m_2 \times 0 = 3 \times 2 + m_2 \times v_2$

$m_2 \times v_2 = 6$

And $e = \frac{v_2 - 2}{4}$

Since $e = 1 \therefore v_2 = 6$ msec

$\therefore m_2 \times 6 = 6$

$m_2 = 1$ kg

Case II

Again from conservation of momentum

$12 + 0 = 3 \times -1 + m_2 v_2$

$\therefore m_2 v_2 = 18$

$e = \frac{v_2 - v_1}{u_1 - 0} = \frac{(v_2 - (-2))}{(u_1 - 0)} = \frac{v_2 + 2}{4}$

$v_2 = 2$ and $m_2 v_2 = 18$ so $m_2 = 9$ kg

So answer is (1, 9) kg

34. Three sets of parallel plates LM, NR and PQ are given in figures 1, 2 and 3. The view factor F_v is defined as the fraction of radiation leaving plate I that 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 ___________

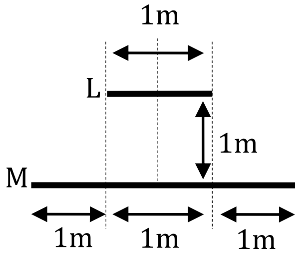


Figure 1

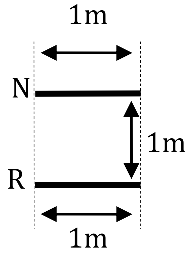


Figure 2

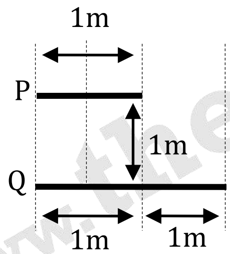
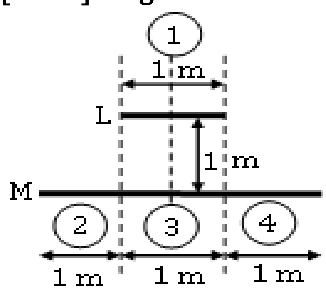
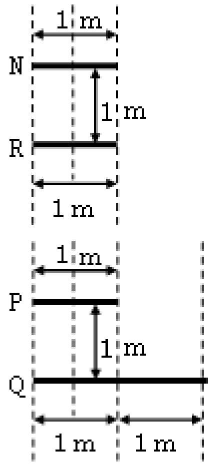


Figure 3

[Ans. *]Range 0.6 to 0.6





$F_{NR} = 0.4$
$F_{LM} = F_{12} + F_{13} + F_{14}$
$F_{13} = F_{NR} = 0.4$
$F_{12} = F_{14}$
$F_{LM} = 0.8 = 0.4 + 2F_{12}$
$0.2 = F_{12}$
$F_{PQ} = F_{12} + F_{13}$
$= 0.2 + 0.4$
$= 0.6$

35. 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 1.0m and that of pipe B is 2.0m. 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 two decimal places).

[Ans. *]Range 0.48 to 0.52

Pipe – A $L_A = 1m$
Pipe – B $L_B = 2m$

$d_A = d_B; h_{fA} = h_{fB}$

$$\frac{32\mu V_A L_A}{wd_A^2} = \frac{32\mu V_B L_B}{wd_B^2}$$

$$\frac{V_B}{V_A} = \frac{d_B^2}{d_A^2} \times \frac{L_A}{L_B}$$

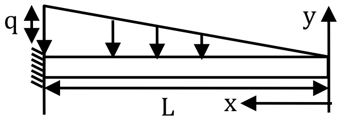
$Q = AV$

$$V = \frac{Q}{\frac{\pi}{4}} d^2$$

$$\frac{\frac{Q_B}{\frac{\pi}{4}d^2B}}{\frac{Q_A}{\frac{\pi}{4}d^2A}} = \frac{d_B^2}{d_A^2} \times \frac{L_A}{L_B}$$

$$\frac{Q_B}{Q_A} = \frac{d_B^2}{d_A^4} \times \frac{L_A}{L_B} = \frac{1}{2}$$

36. 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 :



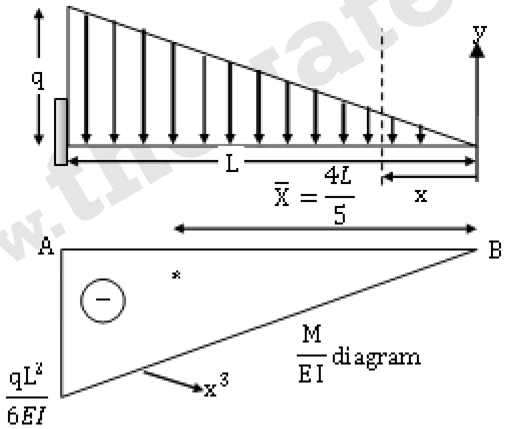
(A) $\frac{qL^4}{10EI}$

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

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

(D) $\frac{qL^4}{15EI}$

[Ans. B]



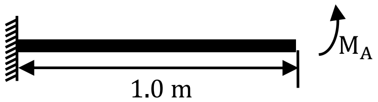
By using moment area IIndtheorem

$$Y_B - Y_A = A\bar{X} \text{of} \frac{M}{EI} \text{ diagram between B and A}$$

$$Y_{max} - 0 = \left(\frac{1}{4}\right)\left(\frac{qL^2}{6EI}\right)(L)\left(\frac{4L}{5}\right)$$

$$y_{max} = \frac{qL^4}{30EI}(\downarrow)$$

37. A horizontal cantilever beam of circular cross-section, length 1.0m 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 one decimal place).



[Ans. *]Range 2.4 to 2.6

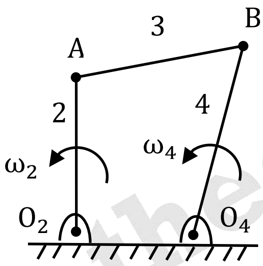
$$Y_{max} = \frac{ML^2}{2EI} = \frac{1 \times 10^3 \times 10^6}{2 \times 200 \times 10^6} = 2.5mm$$

38. 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 of different links are:

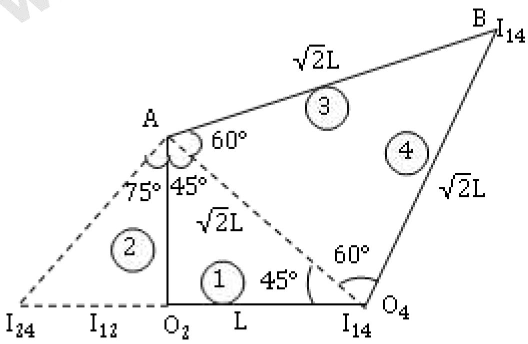
$O_2O_4 = O_2A = L$

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

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).



[Ans. *]Range 0.78 to 0.80

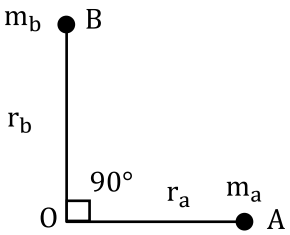


According to Arnold's Kennedy theorem,

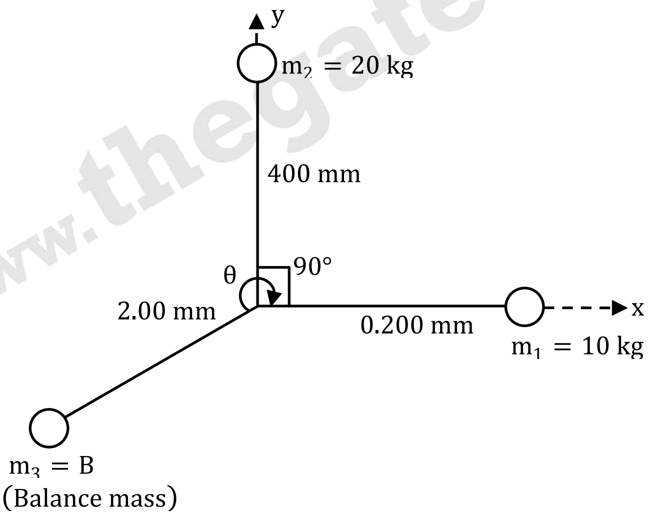
$$\tan 75° = \frac{(I_{24}I_{12})}{(L)}$$

$(I_{24}I_{12}) = (L \tan 75°) = 3.732L$
$(I_{24}I_{14}) = 4.732\ L$
$\omega_2 \times (I_{24}I_{12}) = \omega_4(I_{24}I_{14})$
$\frac{\omega_4}{\omega_2} = \frac{I_{24}I_{12}}{I_{24}I_{14}}$
$\frac{\omega_4}{\omega_2} = \left(\frac{3.732}{4.732}\right) = 0.7886$

39. 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 $r_b = 400$mm, then the balance mass to be places at a radius of 200mm is __________ kg(round off to two decimal places).



[Ans. *]Range 41.00 to 42.00



Unbalance masses lying in same plane so it is problem of static balancing for this
$\sum F_x$ & $\sum F_y = 0$
For given system
$m_1 = 10$ kg $r_s = 0.2$ mtr, $m_2 = 20$ kg $r_2 = 0.4$ m
$m_3 = B, r_3 = 0.2$ m, $\theta_1 = 0°, O_2 = 90°, \theta_3 = \theta$
$\because \sum F_x = 0$ (After introducing balance mass)

$m_1\, r_1\, \omega^2 \cos\theta_1 + m_2\, r_2\, \omega^2 \cos\theta_2 + m_3\, r_3\, \omega^2 \cos\theta_3 = 0$

After putting values

$10 \times 0.2 \times \cos 0 + 20 \times 0.4 \times \cos 90° + B \times 0.2 \times \cos\theta = 0$

$B\cos\theta = -10 \cdots (1)$

Similarly $\sum F_y = 0$

$m_1\, r_1 \sin\theta_1 + m_2\, r_2 \sin\theta_2 + m_3\, r_3 \sin\theta_3 = 0$

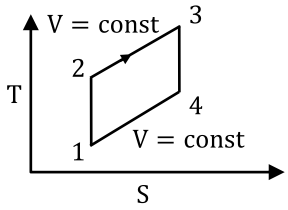
$10 \times 0.2 \times \sin 0 + 10 \times 0.4 \times \sin 90 + B \times 0.2 \times \sin\theta = 0$

$B\sin\theta = -40 \cdots (2)$

$(1)^2 + (2)^2 \Rightarrow B = 41.23\text{ kg}$

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

[Ans. *]Range 705.00 to 715.00



$\eta = 0.5$

Mean $P_r = 1000\text{ kPa}$

$\gamma = 1.4$

$R = 0.287\text{ kJ/kgk}$

$P_1 = 100\text{ kPa}, T_1 = 300\text{ k}$, Work =?

We know $P_m = \dfrac{\text{Work in cycle}}{\text{Stroke volume}}$

$\eta_{otto} = 1 - \dfrac{1}{r^{\gamma-1}} = 0.5$ Where $r = V_1/V_2$

$\left(\dfrac{1}{0.5}\right)^{\frac{1}{r^{\gamma-1}}} = r$

$r = 5.656$

Applying ideal gas laws

$P_1V_1 = m_1RT_1$

Assuming $m_1 = 1\text{ kg}$

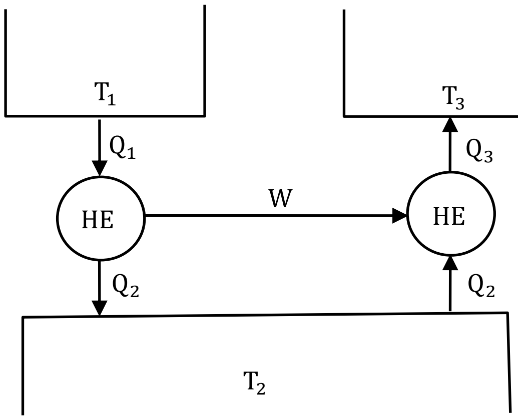
$100 \times 10^3 \times V_1 = 0.287 \times 10^3 \times 300;\ V_1 = 0.861\text{ m}^3$

$V_2 = \dfrac{V_1}{r} = 0.152\text{ m}^3$

Now we know stroke volume $= V_1 - V_2 = 0.708\text{ m}^3$

So workdone $= 1000 \times 10^3 \times 0.708 = 708.77 \times 10^3$ J/kg or 708.77 kJ/kg

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

[Ans. C]

$\eta = \frac{W}{Q_1}$; $COP_{HP} = \frac{Q_3}{W}$

As we have to find the COP of heat Pump, the desired effect is the heat added to higher temperature, hence Q_3

Now applying 1st law of TD

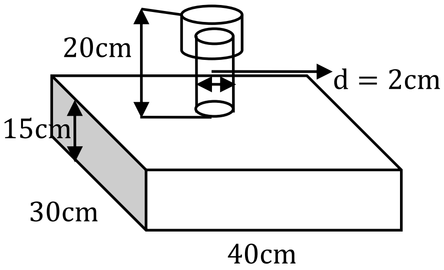
$Q_3 = W + Q_2$ and EW $= Q_1 - Q_2$ so

$\eta_{HE} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$;

$COP_{HP} = \frac{Q_2 + Q_1 - Q_2}{Q_1 - Q_2} = \frac{Q_1}{Q_1 - Q_2}$

Clearly $\eta = \frac{1}{COP}$ or $COP = \eta^{-1}$

42. 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 $40cm \times 30cm \times 15cm$) is ______



[Ans. *]Range 28.80 to 29.00

$$\text{Pouring time} = \frac{\text{Volume}}{\text{Velocity} \times \text{Area}} = \frac{30 \times 40 \times 15}{\sqrt{2 \times 981 \times 20} \times \frac{\pi}{4} \times 2^2}$$

$$= \frac{30 \times 40 \times 15}{622.32} = 28.92 \text{ sec}$$

43. 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

$$\left(\frac{\text{Exact value} - \text{Approximate value}}{\text{Exact value}}\right) \times 100.$$

The percentage error in the derivative of

$f(x)$ at $x = \frac{\pi}{6}$ radian, choosing $h = 0.1$ radian is

(A) <0.1%

(B) >0.1% and <1%

(C) >1% and <5%

(D) >5%

[Ans. B]

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

$$= \frac{-\frac{1}{2}\sin(0.1)}{0.1} = -0.998 \times 0.5 = -0.49916$$

$$f(x) = \cos x$$

$$l'(z) = \sin x$$

$$= -\sin\left(\frac{\pi}{6}\right) = -0.5$$

$$\frac{TV - AV}{TV} \times 100 = \frac{-0.5 - (-0.49916)}{-0.5} = -0.0016 \times 100 = -0.16$$

$$\%\varepsilon = 0.16\%$$

44. 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 constants 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) $y = \frac{C_1}{x^2} + C_2x + 2$

(D) $y = C_1x^2 + C_2x + 4$

[Ans. A]

Let $x = e^z$

$$\frac{d^2}{dx^2} = \theta(\theta - 1);$$

$$\frac{d}{dx} = \theta$$

CF:

$$\theta(\theta - 1)y - 2\theta y + 2y = 0$$

$$(\theta^2 - 3\theta + 2)y = 0$$

$$\theta = 1,2$$

$$y_{cf} = C_1e^z + C_2c^{2z}$$

$$y_{CF} = C_1e^z + C_2c^{2z}$$

$$= C_1x + C_2x^2$$

$$\frac{d}{dz} = \theta$$

$$PI = \frac{4e^{0z}}{(\theta^2 - 3\theta + 2)} = \frac{4}{2} = 2$$

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

[Ans. *]Range 0.7 to 0.7

Power supplied

$$V \times I = 20 \times 250$$

Heat supplied to weld $= 0.7 \times 20 \times 250$

Heat input per unit length $= \frac{0.7 \times 20 \times 250}{5} = 0.7$ kJ/mm

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

[Ans. *]Range 274.00 to 276.00

$$\text{Feed velocity} = \frac{f \times N}{60} = \frac{0.25 \times 1200}{60} = 5\ \text{mm/sec}$$

$$\text{MRR} = \frac{\pi}{4} d^2 \times 5\ \text{mm/s}$$

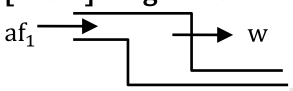
$$= \frac{\pi}{4} \times 10^2 \times 5$$

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

$$P = \text{SCE} \times \text{MRR} = 0.7 \times \frac{\pi}{4} \times 10^2 \times 5 = 274.89\ \text{W}$$

47. Water flowing at the rate of 1kg/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 2.50kW. there is no other work or heat interaction between the system and the surroundings. Assuming an ambient temperature of 300K, the irreversibility rate of the system is ____kW (round off to two decimal places).

[Ans. *]Range 2.05 to 2.15



Considering steady flow, irreversibility is the loss of available energy

Where, a_f = Availability function in open system

w = work done by the system

I = irreversibility

$$I = a_{f1} - (af_2 + w)$$

Irreversibility =Loss in available energy

Since, electric work is supplied to the system, $w = -2.5$ kW

$$\text{So, } I = h_1 - T_a S_1 + \frac{V_1^2}{2} + gz_1 - \left(h_2 - T_a S_2 + \frac{V_2^2}{2} + gZ_2 - 2.5\right)$$

$$I = h_1 - h_2 - T_a(S_1 - S_2) + \frac{V_1^2 - V_2^2}{2} + g(z_1 - z_2) + 2.5$$

Ignoring charge in KE and PE

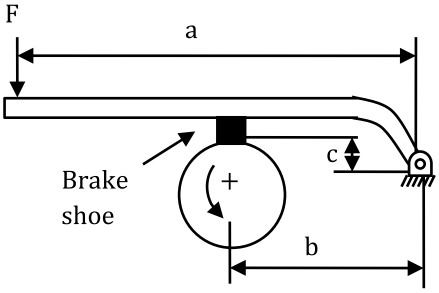
$$I = -(h_2 - h_1) + T_a(S_2 - S_1) + 2.5$$

$$\text{Given} : \Delta h = h_2 - h_1 = 2.5\ \text{kJ/kgk}$$

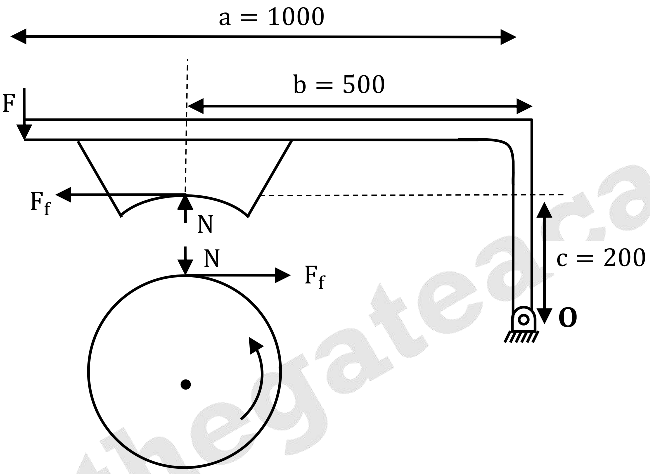
$$\Delta S = S_2 - S_1 = 0.007\ \text{kJ/kgk}$$

$$I = -2.5 + 300(0.007) + 2.5; I = 2.1\ \text{kJ/kg}$$

48. A short shoe external drum brake is shown in the figure. The diameter of the brake drum is 500mm. the dimensions a=1000 mm, b=500 mm and c=200mm. the coefficient of friction between the drum and the shoe is 0.35. the force applied on the lever F=100N 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).



[Ans. *]Range 19.00 to 21.00



Taking moment about O

$\sum M_o = 0$

$F \times 1 + F_f \times 0.2 = N \times 0.5$

$F_f = \mu_N = 0.35\ N$

$(100 \times 1) + (0.35N \times 0.2) = 0.5N$

$N = 232.558$

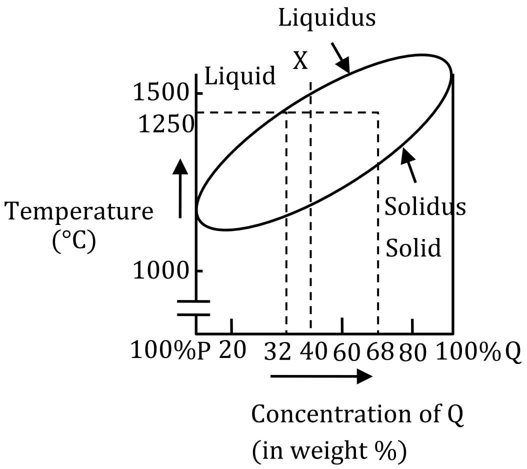
$\text{Braking Torque(T)} = F_f \times r$

$= \mu N \cdot \frac{d}{2}$

$= 0.35 \times 232.558 \times \left(\frac{0.500}{2}\right)$

$T = 20.349\ \text{Nm}$

49. The binary phase diagram of 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 soild state. The fractions of soild and liquid (in weight percent) at $1250°C$, respectively will be



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

[Ans. B]

According to lever rule:

$$\text{Amount of solid phase } = \frac{(40-32)}{(68-32)} \times 100 = 22.2\%$$

$$\text{Amount of liquid phase } = \frac{(68-40)}{(68-32)} \times 100 = 77.8\%$$

50. In an orthogonal machining with a signal 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).

[Ans. *]Range 0.72 to 0.76

$$r = \frac{t_1}{t_2} = \frac{0.125}{0.22} = 0.5681$$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.5681\cos 10}{1 - 5.681\sin 0}$$

$$\phi = \tan^{-1}\left(\frac{0.5681\cos 10}{1-0.5681}\sin 10\right) = 31.82°$$

$$2\phi + \beta - \alpha = 90 \rightarrow \beta = 90 + \alpha - 2\phi$$

$$= 90 + 10 - 63.65 = 36.64°$$

$$\mu = \tan\beta = \tan(36.34) = 0.735$$

51. An idealized centrifugal pump (blade outer radius of 50mm) consumers 2 kW power while running at 300. 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 two decimal places).

[Ans. *]Range 8.00 to 8.20

$r_{out} = 50$ mm

So $d_{out} = 100$ mm

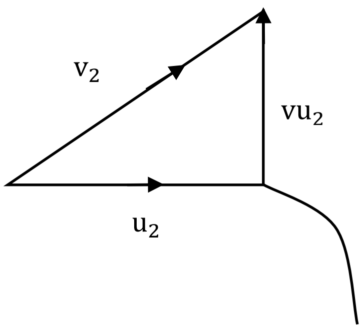
$P = 2 \times 10^3 W$

$N = 3000$

$V_{entry} =$ Axial

$V_{r2} =$ Radial

$\dot{m} = ?$



$P = \rho QgH$

$P = \dot{m}C(V_{\omega 2} \times u_2 - V_{\omega 1} \times u_1)$

As $V_2 =$ axial, $V_{\omega 1} = 0$

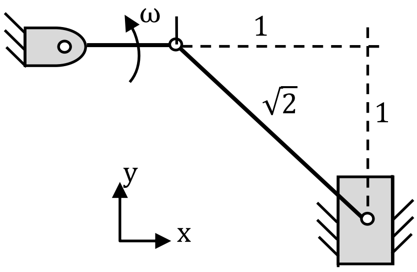
$V_{\omega 2}$ from outlet velocity triangle we conclude $V_{\omega 2} = v_2$, so

$P = \dot{m}(u_2^2)$

$2 \times 10^3 = m(15.707)^2, u_2 = \dfrac{\pi dN}{60}, u_2 = 15.707$

$m = 8.10$ kg/s

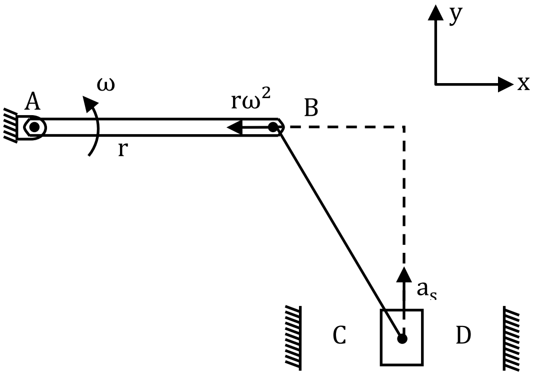
52. The crank of a slide - crank mechanism rotates counter – clockwise (CCW) with a constant angular velocity ω, as shown. Assume the length of the crank to be r.



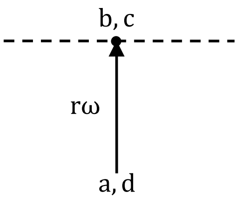
Using exact analysis, the acceleration of the slider in the y – direction, at the instant shown where the crank is parallel to x – axis, is given by

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

[Ans. C]



Draw it's velocity diagram

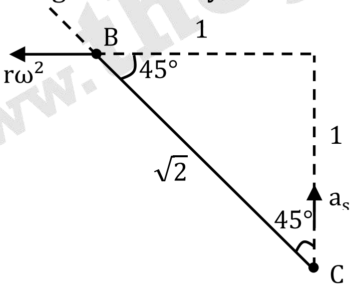


From here

$V_{BC} = 0$

i.e. $\omega_{bc} = 0$

∴ Angular velocity of link BC is zero. So it's radial acceleration will also be zero.



Radial acceleration of link = 0

(Acceleration along link)

$r\omega^2 \cos 45° - a_s \cos 45° = 0$

$\Rightarrow a_s = r\omega^2$

53. 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 the rotating rolls unaided. If the initial sheet thickness is 2mm, the minimum possible final thickness that can be produced by this process in a single pass is ________ mm (round off to two decimal places).

[Ans. *]Range 1.24 to 1.26

$\Delta H_{max} = \mu^2 R = (0.5)^2 \times 300 = 0.75$ mm

$\Delta H_{max} = H_0 - H_1$

$H_1 = H_0 - \Delta H_{max} = 2 - 0.75 \text{ mm} = 1.25$ mm

54. Given a vector $\bar{u} = \frac{1}{3}(-y^3\hat{\imath} + x^3\hat{\jmath} + z^3\hat{k})$ 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 $\int (\nabla + \bar{u}) . \hat{n}\, dS$ evaluated on the curved surface of the hemisphere S is

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

(B) π

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

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

[Ans. C]

Given $\bar{u}$ is differentiable vector in the given open surface bounded by closed contour C i. e. $C: x^2 + y^2 = 1, z = 0$

By stoke's theorem

$$\iint_S \text{curl}\,\vec{F}.\hat{n}ds = \oint_c \bar{F}.\overline{dr}$$

$$\iint_S (\nabla \times \bar{u}).\hat{n}ds = \oint_c \bar{u}.\overline{dr}$$

$$= \frac{1}{3}\oint -y^3dx + x^3dy \;(\because z = 0)$$

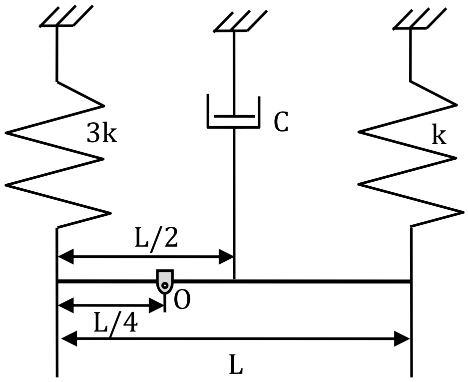
$C: x = \cos\theta \Rightarrow dx = -\sin\theta \Rightarrow dy = \cos\theta d\theta;\ \theta : 0 \text{ to } 2\pi$

$$= \frac{1}{3}\int_0^{2\pi} \sin^4\theta d\theta + \frac{1}{3}\int_0^{2\pi} \cos^4\theta d\theta$$

$$= \frac{4}{3}\int_0^{\pi/2} \sin^4\theta d\theta + \frac{4}{3}\int_0^{\pi/2} \cos^4\theta d\theta$$

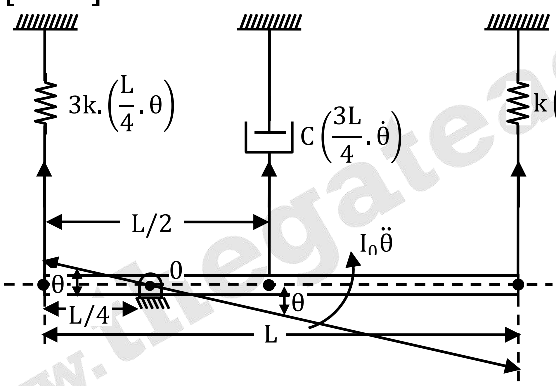
$$= \frac{4}{3}\left(\frac{3}{4}\times\frac{1}{2}\times\frac{\pi}{2} + \frac{3}{4}\times\frac{1}{2}\times\frac{\pi}{2}\right) = \frac{\pi}{2}$$

55. A slender uniform ridge bar of mass m is hinged at O and supported by two springs, with stiffness 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
(C) 2
(D) $4\sqrt{7}$

[Ans. D]



Using De-Alembert method

$$I_0\ddot{\theta} + C\left(\frac{L}{4}\dot{\theta}\right) \times \frac{L}{4} + k\left(\frac{3L}{4}.\theta\right) \times \frac{3L}{4} + 3k\left(\frac{L}{4}.\theta\right) \times \frac{L}{4} = 0$$

$$I_0\ddot{\theta} + \frac{CL^2}{16}\dot{\theta} + \frac{12\,kL^2}{16}\theta = 0$$

$$\frac{7\,m\,L^2}{48}\ddot{\theta} + \frac{C\,L^2}{16}\dot{\theta} + \frac{12\,kL^2}{16}\theta = 0 \left\{I_0 = I_g + mx^2 = \frac{m\,L^2}{12} + m\left(\frac{L}{4}\right)^2 = \frac{7\,m\,L^2}{48}\right\}$$

$$\frac{7m}{48}\ddot{\theta} + \frac{C}{16}\dot{\theta} + \frac{12\,k}{16}\theta = 0 \rightarrow \text{(equation of motion)}$$

For critical damping $\because \varepsilon = 1 = \dfrac{\text{Damping Cofficient}}{\text{Critical Damping Coeficient}}$

$$\text{i.e. } 1 = \frac{\frac{C}{16}}{\frac{2\sqrt{12k}}{16} \times \frac{7m}{48}}$$

$$\Rightarrow \frac{C}{\sqrt{km}} = 4\sqrt{7}$$