BYJU'S EXAM PREP

GATE 2019

Set-2

Mechanical Engineering

Questions & Solutions

SECTION: GENERAL APTITUDE

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

A. desperation B. insinuation
C. consultation D. culmination

Ans. D

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

Meaning of culmination is the highest or climactic point of something, especially as attained after a long time

Hence, it is the most appropriate word

2. If IMHO = JNIP; IDK = JEL; and SO = TP, then IDC = __________.

A. JDC B. JCD
C. JDE D. JED

Ans. D

Sol. I + 1 = J, M + 1 = N, H + 1 = I, O + 1 = P; I + 1 = J, D + 1 = E, K + 1 = L; S + 1 = T, O + 1 = P

Hence, IDC will be written as JED

I + 1 = J, D + 1 = E, C + 1 = D

3. Are there enough seats here? There are __________ people here than I expected.

A. many B. most
C. more D. least

Ans. C

Sol. Comparison is made here between the number of people and number of seats, hence, **more** is the most appropriate word

4. 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. might be B. are going to be
C. will be D. were to be

Ans. C

Sol. Future is being discussed here, hence will be is the most appropriate phrase

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. 7 B. 6
C. 8 D. 9.5

Ans. A

Sol. XYZ = 192 and Z = 4

So, XY = 48

$$P = \frac{X+Y}{2}$$

For finding the minimum possible of P, X + Y should be minimum

Now, the possible values of X and Y are as follows

X	Y
48	1
24	2
16	3
12	4
8	6

So, from this we can clearly see that X + Y will be minimum only when X = 8 and Y = 6 or vice-versa

So minimum value of $P = \frac{8+6}{2} = 7$

6. 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 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. Most households that subscribe to X's loyalty membership discontinue watching cable television

B. Non-members prefer to watch cable television

C. The X is cancelling accounts of non-members

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

Ans. A

Sol. option A is the most appropriate solution

7. 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. 35.70

B. 10.00

C. 37.50

D. 25.00

Ans. C

Sol. Let the GDP in 2015 = x

Then, the GDP in 2016 will be

= 1.1x

So, fiscal deficit in 2015

$= 0.04 \times x = 0.04x$

And the fiscal deficit in 2016

$= 0.05 \times 1.1x = 0.055x$

Increase in fiscal deficit

= 0.055x – 0.04x = 0.015x

So, the percentage increase in fiscal deficit = $\frac{0.015x}{0.04x} \times 100 = 37.5\%$

8. 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. 16.50 B. 14.50

C. 15.50 D. 13.50

Ans. B

Sol. 1 hour work of P = 1/6

1 hour work of Q = 1/9

1 hour work of R = -1/12 (negative sign indicates that its emptying the tank)

Tank filled when P and R works initially for 4 hours

$= 4(^1/_6 - ^1/_{12}) = ^1/_3$

Tank filled by when Q and R works for another 6 hours

$= 6(^1/_9 - ^1/_{12}) = ^1/_6$

Total tank filled in these 10 hours = $^1/_3 + ^1/_6 = 0.5$

So, the remaining half tank will be filled by Q alone in 4.5 hours (Since Q can fill the complete tank in 9 hours)

Therefore, total time required to fill the tank = 4 + 6 + 4.5 = 14.5 hours

9. 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 Manhattam 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

Ans. C

Sol. option C is the most appropriate solution

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 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. 23.97

C. 25.86

D. 16.24

Ans. B

Sol. Revenue contributed by Pool = 170 + 320 + 215 + 190 = 895

Revenue contributed by Mini = 110 + 220 + 180 + 70 = 580

Revenue contributed by Prime = 75 + 180 + 120 +90 = 465

Total revenue of Mola = 895 + 580 + 465 = 1940

So, the percentage share = $\frac{465}{1940} \times 100 = 23.97\%$

MECHANICAL ENGINEERING

1. 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.

Ans. 50

Sol. Tensile stress

$$\sigma = \frac{E}{R} y = \frac{100 \times 10^3}{1} \left(\frac{1}{1000 \times 2}\right)$$

$$= 50 \text{ MPa}$$

2. 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. 1

Sol: $E = \frac{1}{2} \times \text{Capacitance} \times \text{voltage}^2$

$$E = 0.5 \times 50 \times 10^{-6} \times 200^2 = 1 \text{ J}$$

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

Ans. 3

Sol. $x = \frac{3+x+2+4}{4}$

$4 \times x = 3 + x + 2 + 4$

$4 \times x - x = 3 + 2 + 4 = 9$

$x = 3$

Mode is 3.

(Maximum repeated value)

4. 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. Knurling

C. Roll forming D. Chamfering

Ans. B

Sol. We provide special pattern to prevent the relative motion between contact surface. This special pattern is known as Knurling.

5. 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. decrease in the surface roughness and decrease in the size of the beam

C. decrease in the surface roughness and increase in the size of the beam

D. increase in the surface roughness and decrease in the size of the beam

Ans. A

Sol. Formula for endurance limit

$\sigma_e = K_a \times K_b \times K_c \times K_d \times \sigma'_e$

Where

K_a – Size factor

K_b – Surface factor

K_c – load factor

K_d – Temperature factor

σ'_e – Endurance Strength

Form above formula it is clear that the Endurance limit increases with increase in size, surface, load, temp and endurance strength.

6. 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. 15

C. 8 D. 16

Ans. D

Sol. [A] {X} = {R}.

We know

$$AX = \lambda X\ ; \text{Where } \lambda - \text{Eigen Value}$$

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

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

Hence, $\lambda = 16$

7. 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. 500

Sol. Reynold's Number

$$Re = \frac{\rho V_{av} D}{\mu}$$

Where: -

ρ – Fluid Density

V_{av} – Average velocity

D – Dimeter of Pipe

μ – Dynamic viscosity of Fluid

$$Re = \left(\frac{\rho V_{av} D}{\mu}\right) = \left(\frac{\rho \left(\frac{Q_{pipe}}{A_{pipe}}\right) D}{\mu}\right)$$

From above expiration, Reynold's Number is independent of flow profile. Hence, Reynold's Number for parabolic flow profile is 500.

8. 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. $\left(\frac{\partial p}{\partial v}\right)_T$ B. $\left(\frac{\partial s}{\partial T}\right)_p$

C. $\left(\frac{\partial T}{\partial p}\right)_s$ D. $-\left(\frac{\partial T}{\partial v}\right)_p$

Ans. C

Sol. From mathematical relation expiration

$$dx = Mdy + Ndz$$

$$\Rightarrow \left(\frac{\partial M}{\partial z}\right)_y = \left(\frac{\partial N}{\partial y}\right)_z$$

From Maxwell relation

$$dh = Tds + Vdp$$

$$\therefore \left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial V}{\partial S}\right)_p$$

9. Hardenability of steel is a measure of

A. the ability to harden when it is cold worked

B. the maximum hardness that can be obtained when it is austenitized and then quenched

C. the ability to retain its hardness when it is heated to elevated temperatures

D. the depth to which required hardening is obtained when it is austenitized and then quenched

Ans. D

Sol. The depth to which required hardening is obtained when it is austenitized and then quenched.

10. 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 B. $\sqrt{2}$

C. $4\sqrt{2}$ D. $2\sqrt{2}$

Ans. D

Sol. Directional derivative of function along the line is the scalar value of derivative along the line. i.e. we have to calculate value of derivative of function in the direction of given line vector

$$\nabla f = \hat{i}\left(\frac{\partial f}{dx}\right) + \hat{j}\left(\frac{\partial f}{dy}\right)$$

$$\nabla f = 2\hat{i} + 2\hat{j}$$

Now, calculating the value of ∇f in $1\hat{i} + 1\hat{j}$

D.D of given function is

$$(2\hat{i} + 2\hat{j}) \cdot \frac{(\hat{i} + \hat{j})}{|\hat{i} + \hat{j}|} = 2\sqrt{2}$$

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

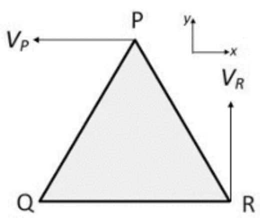
A. $\frac{2\pi D}{T}$ B. $\frac{T}{D}$

C. $\frac{\pi D}{T}$ D. $\frac{D}{T}$

Ans. C

Sol. circular pitch = $\frac{\pi D}{T}$

12. 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

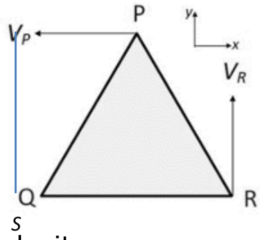


A. $V_R/\sqrt{3}$ B. $V_P/\sqrt{3}$

C. $2V_R$ D. $2V_P$

Ans. C

Sol. The given body is a rigid body; Hence the given body will not have any deformation, and the possible motion is translation and angular motion. we know that the angular motion of the object is always defined as the motion about the point. Hence, first we have to find a point parallel to both velocity V_P and V_R.



∴ Angular velocity,

$$\omega = \frac{\text{Velocity}}{\text{Perpendicular distance}}$$

$$\omega = \frac{V_p}{PS} = \frac{V_R}{SR}$$

$$PS = \frac{\sqrt{3}}{2} \times \text{Side of triangle} = \frac{\sqrt{3}}{2} \times 1 = \frac{\sqrt{3}}{2}$$

$$SR = \frac{1}{2} \times \text{Side of triangle} = \frac{1}{2} \times 1 = \frac{1}{2}$$

$$\omega = \frac{2V_p}{\sqrt{3}} = \frac{2V_R}{1}$$

13. 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. 0.25 B. 0.0625

C. 1.0 D. 0.5

Ans. C

Sol. $F_{12} = 1$

14. 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. $\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$ D. $\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$

Ans. C

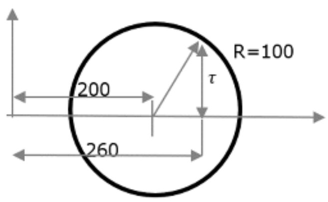
Sol. The transformation matrix for mirroring a point in x – y plane about the line y = x is given by

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

15. 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. 80

Sol.



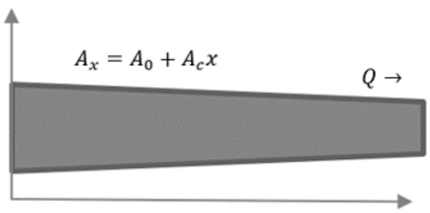
$\tau = \sqrt{100^2 - 60^2} = 80\ \text{MPa}$

16. 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. Exponential
C. Logarithmic
D. Linear

Ans. C

Sol. Let the given body cross-sectional area varies linearly, and heat is flowing from left to right.



If there is no heat generation,

$$\frac{d}{dx}\left(-KA\frac{dT}{dX}\right) = 0$$

$$\int \frac{d}{dx}\left(-KA\frac{dT}{dX}\right) = \int 0$$

$$\left(-KA\frac{dT}{dx}\right) = C$$

$$-K(A_0 + A_c x)\frac{dT}{dX} = C$$

$$dT = \frac{-C\,dX}{K(A_0 + A_c x)}$$

$$\int_1^2 dT = \int_1^2 \frac{-C\,dX}{K(A_0 + A_c x)}$$

$$T_2 - T_1 = -\frac{C}{K}\ln\left(\frac{A_c x_2 + A_0}{A_c x_1 + A_0}\right)$$

17. An analytic function f(z) of complex variable z = x + I y 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 $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$

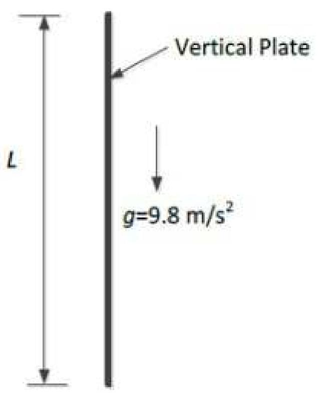
Ans. C

Sol. If f(z) = u(x, y) + iv(x, y) is analytic function then it must satisfy the following relations.

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

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

18. 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 given as Nu = K Ra ¼, 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 ratio h_1/h_2 is_____________.

Ans. 2

Sol. $N_u = K\,(R_a)^{\frac{1}{4}}$

We know that $R_a = G_r P_r$

$N_u = K\,(G_r P_r)^{\frac{1}{4}}$

$\frac{hL}{K} \propto (G_r)^{\frac{1}{4}} \propto \left(\frac{g\beta\Delta T L^3}{V^2}\right)^{\frac{1}{4}}$

$hL \propto L^{\frac{3}{4}}$

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

$\frac{h_2}{h_1} \propto \left(\frac{L_1}{L_2}\right)^{\frac{1}{4}} \Rightarrow \frac{h_1}{h_2} \propto \left(\frac{L_2}{L_1}\right)^{\frac{1}{4}} = (16)^{\frac{1}{4}} = 2$

19. 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. Decreasing the condenser pressure.

B. Increasing the boiler pressure.

C. Decreasing the boiler pressure.

D. Increasing the turbine inlet temperature.

Ans. D

Sol. Due to increase of the turbine inlet temperature, quality of the stream at outlet of the turbine improves. Which increases the thermal efficiency and reduces the moisture content of the steam at the turbine outlet.

20. Consider a linear 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. (0.5, 0.0) B. (0.35, -0.15)

C. (0.5, -0.5) D. (0.5, -0.15)

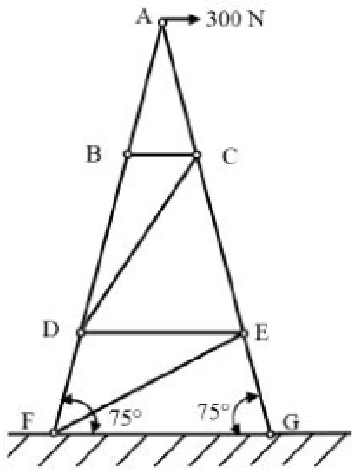
Ans. D

Sol. $\epsilon_1 = \frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E} = \frac{100}{200} - 0.3 \times \frac{0}{200} = 0.5$

$\epsilon_2 = \frac{\sigma_2}{E} - \mu\frac{\sigma_1}{E} = \frac{0}{200} - 0.3 \times \frac{100}{200}$

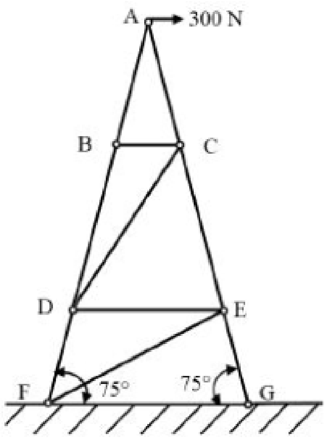
$= -0.15$

21. 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

Sol.



The momentum about the point A must be zero, because there is no deformation of any truss.

Hence, $F_{CD} = 0$ [F_{CD} is not passing through the point A]

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

A. freezing range

B. surface tension

C. degree of superheat

D. viscosity

Ans. C

Sol. Fluidity of molten metal of cast alloys increases with increase in degree of superheat.

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

A. Ring gage

B. Snap gage

C. Plug gage

D. Master gage

Ans. C

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

24. 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. $y = e^{-4x} + 1.25$ B. $y = e^{4x} + 5$

C. $y = e^{4x} + 1.25$ D. $y = e^{-4x} + 5$

Ans. A

Sol. The given equation is.

$$\frac{dy}{dx}+4y=5$$

If Integration factor $= e^{\int 4dx} = e^{4x}$

⇨ $y \times IF = \int 5 \times IF\, dx + C$

⇨ $y \times e^{4x} = 5 \times \frac{e^{4x}}{4} + C$

⇨ $y \times e^{4x} = 5 \times \frac{e^{4x}}{4} + C....(1)$

Now for at x=0,

⇨ $2.25 = \frac{5}{4} + C$

⇨ $C = 1$

⇨ Using the value of C in equ (1)

⇨ $y \times \frac{e^{4x}}{e^{4x}} = \frac{5}{e^{4x}} \times \frac{e^{4x}}{4} + \frac{C}{e^{4x}}$

⇨ $y = 1.25 + e^{-4x}$

25. 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. $-\rho\left(x^2\hat{i} + y^2\hat{j}\right)$ B. $-\rho\left(x\hat{i} + y\hat{j}\right)$

C. $\rho\left(x\hat{i} + y\hat{j}\right)$ D. $\rho\left(x\hat{i} - y\hat{j}\right)$

Ans. B

Sol. Euler's Equation of motion in 2D.

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = f_x - \frac{1}{\rho}\frac{\partial p}{\partial x}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = f_y - \frac{1}{\rho}\frac{\partial p}{\partial y}$$

As there is no extra force acting on the fluid.

$f_x \text{ and } f_y = 0$

Now form the given expiration,

u=x & v=y

$$\therefore \frac{\partial x}{\partial t} + x\frac{\partial x}{\partial x} + y\frac{\partial x}{\partial y} + w\frac{\partial x}{\partial z} = 0 - \frac{1}{\rho}\frac{\partial p}{\partial x}$$

$$\frac{\partial y}{\partial t} + x\frac{\partial y}{\partial x} + y\frac{\partial y}{\partial y} + w\frac{\partial v}{\partial z} = 0 - \frac{1}{\rho}\frac{\partial p}{\partial y}$$

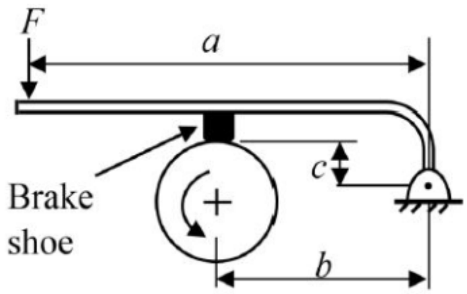
$$\therefore 0 + x \times 1 + 0 + 0 = 0 - \frac{1}{\rho}\frac{\partial p}{\partial x}$$

$$0 + 0 + y \times 1 + 0 = 0 - \frac{1}{\rho}\frac{\partial p}{\partial y}$$

$$\therefore \text{Press Grad Vec} = \frac{\partial p}{\partial x}\,\hat{i} + \frac{\partial p}{\partial y}\,\hat{j}$$

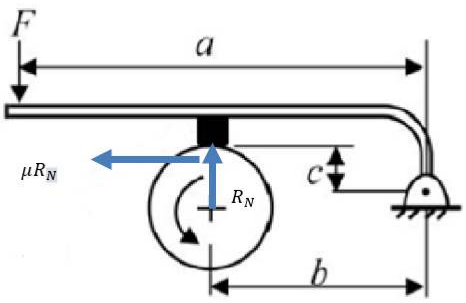
$$= -\rho\,(x\,\hat{i} + y\,\hat{j})$$

26. 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).



Ans. 20.34

Sol.



Applying momentum about point O.

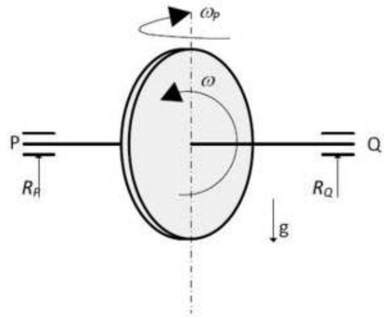
$\sum M_H = 0$

$F \times a + \mu R_N \times c - R_N \times b = 0$

$R_N = 232.55$

Breaking Torque = $\mu R_N R_N$ = 20.34

27. 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 1.5r. 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 ω_P = ω/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/s² and g = 10 m/s², the ratio of the larger to the smaller bearing reaction force (considering appropriate signs) is __________.



Ans. -3

Sol. Gyroscope couple (GC) = $I\omega\omega_p$

Using: $\omega_p = \frac{\omega}{10}$ and $\omega^2 r = 300$

$GC = \frac{mr^2}{2}\frac{\omega^2}{10} = 15mr$

Reaction at P and Q due to gravity

$R_{p1} + R_{q1} = mg = 10m$

$R_{p1} = 5m$

$\therefore R_{q1} = 5\ m$

Reaction at P and Q due to GC

Taking momentum about point p.

$R_{q2} \times 1.5r - 15mr = 0$

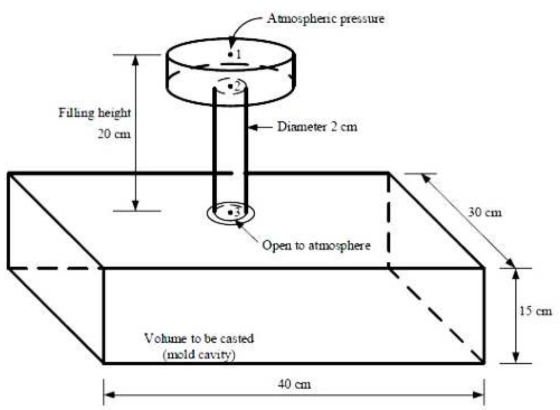
$R_{q2} = \frac{15mr}{1.5r} = 10\ m$

$\therefore R_{p2} = -10\ m$

Now,

$\frac{R_Q}{R_P} = \frac{R_{q1} + R_{q2}}{R_{P1} + R_{P2}} = \frac{5+10}{5-10} = -3$

28. 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/s². 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 ____________



Ans. 29.84

Sol. $\text{Mold+filling+time+} = \frac{V_m}{A_g.\sqrt{2gh}}$

$$\text{Time} = \frac{0.40 \times 0.30 \times 0.15}{\pi\frac{0.02^2}{4}.\sqrt{2 \times 9.81 \times 0.20}}\ 28.94 \text{ Sec}$$

29. 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.

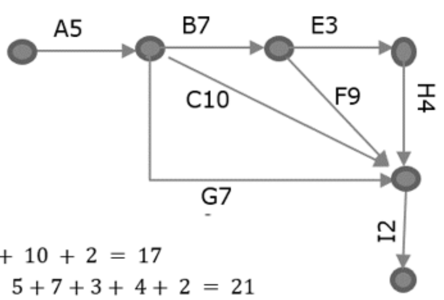
Activity	Duration (Weeks)	Precedence Relationship
A	5	A < B, C, D
B	7	B < E, F, G
C	10	C < I
D	6	D < G
E	3	E < H
F	9	F < I
G	7	G < I
H	4	H < I
I	2	---

A. 21 B. 25

C. 23 D. 17

Ans. C

Sol.



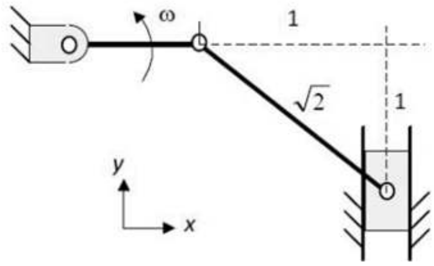
$ACI = 5 + 10 + 2 = 17$

$ABEHI = 5 + 7 + 3 + 4 + 2 = 21$

$ABFI = 5 + 7 + 9 + 2 = 23$

$ABGI = 5 + 7 + 7 + 2 = 21$

30. 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.



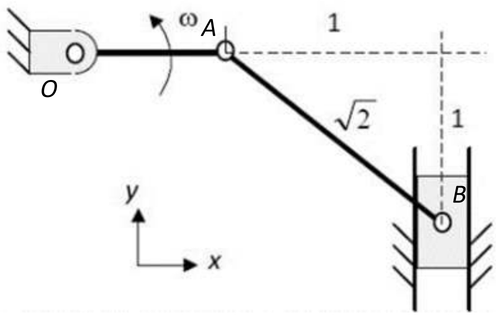
Using exact analysis, the acceleration of the slider in the y-direction, at the instant shown, where the crank is parallel to x-axis, is given by

A. $-\omega^2 r$ B. $2\omega^2 r$

C. $\omega^2 r$ D. $-2\omega^2 r$

Ans. C

Sol.



Velocity of point A, $V_A = r \times \omega$

The radial acceleration of point A, $a_{oa} = r\omega^2$

Since, the inclination of line AB is 45 degree, the acceleration of the point B will be equal to the acceleration of point A. i.e. $r\omega^2$

31. 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 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. 0.7

Sol. Heat input $= \eta \times \text{Power}_{elec}$

Heat input $= 0.7 \times 250 \times 20$

$= 3500$ **Watt**

Heat input per unit length $= \frac{3500}{5} = 700 \frac{J}{mm}$

=0.7 KJ/mm

32. 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 two decimal places).

Ans. 0.5

Sol. Frictional losses of pipe

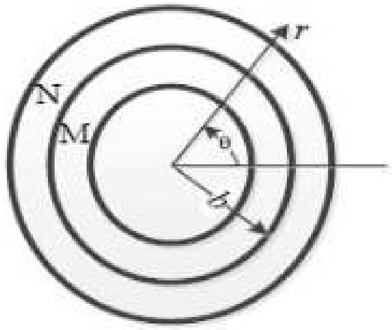
$$hf \propto \mathbf{fL}\frac{\mathbf{V^2}}{\mathbf{D}} \propto \mathbf{fL}\frac{\left(\frac{Q}{A}\right)^2}{\mathbf{D}} \propto \mathbf{fL}\frac{\mathbf{Q^2}}{\mathbf{D^5}}$$

$$\frac{h_{fB}}{hfA} = \frac{f_B\, L_B Q_B^2}{f_A\, L_A Q_A^2}\ ;\text{Where } f = \frac{64}{Re}$$

$$\frac{Q_B^2}{Q_A^2} = \frac{h_{fB}L_A f_A}{hf_A L_B f_B} = \frac{L_A f_A}{L_B f_B} = \frac{L_A Q_B}{L_B Q_A}$$

$$\frac{Q_B}{Q_A} = \frac{L_A}{L_B} = 0.5$$

33. 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. $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$ and $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$

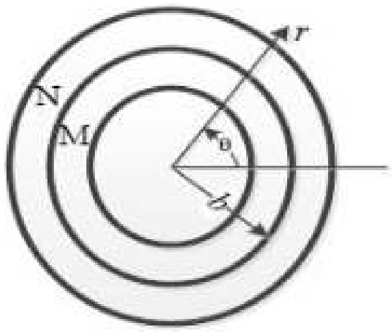
B. $\sigma_{rr}^M = \sigma_{rr}^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only

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 $\sigma_{rr}^M = \sigma_{rr}^N$ only

Ans. D

Sol.

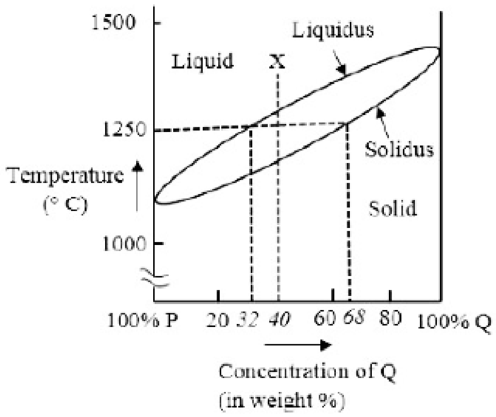


Internal pressure causes the stress in radial as well as circumferential direction.

At r=b i.e. interference of the cylinder can be frictionless if Stress in radial direction must be equal. Velocity in radial direction must be equal. (This condition will make the normal force Zero)

As radius of the cylinder increases due to inside pressure, there will be relative velocity between the contact surfaces in the circumferential direction.

34. 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 solid state. The fractions of solid and liquid (in weight percent) at 1250°C, respectively, will be



A. 22.2% and 77.8%

B. 68.0% and 32.0%

C. 77.8% and 22.2%

D. 32.0% and 68.0%

Ans. A

Sol. Mass fraction of liquid $=\frac{C_\alpha - C_0}{C_\alpha - C_L}$

$$M_L = \frac{68-40}{68-32} = 0.778 = 77.8\%$$

$$M_s = 1 - M_L = 0.222 = 22.2\%$$

35. 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. 943.59

Sol. Annual Demand (D) = 10000 nos

Order Quantities (Q) = 400 / order

Holding cost (C_h)= 24 /valve/year

Ordering Cost (C_0) = RS 400 /order

$$TIC = \frac{D}{Q} C_0 + \frac{Q}{2} C_h$$

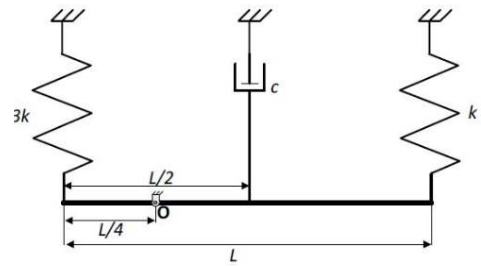
$$TIC = \frac{10000}{400} 400 + \frac{10000}{2} 24 = 14800$$

$$TIC *= \sqrt{2DC_0C_h}$$

$$TIC *= 13856.41$$

$$\text{Saving} = 14800 - 13856.41 = \mathbf{Rs. 943.59}$$

36. 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/√km should be



A. 4

B. 2

C. 4√7

D. 2√7

Ans. C

Sol. $\frac{c}{\sqrt{km}}$

$=?$; When System is critically damped

Suppose that we apply a external force downward at horizontal road at spring constant 3K and leave it freely for to and fro motion.

Therefore, moment about point "O"; $\sum M_0 = 0$

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

$$I_0\ddot{\theta} + K\left(\frac{9L^2}{16}\theta\right) + 3K\left(\frac{L^2}{16}\theta\right) + C\left(\frac{L^2}{16}\dot{\theta}\right) = 0$$

Now, moment of inertia of rod about the center of the rod is

$$I_C = \frac{mL^2}{12}$$

And moment of inertia about the hinged point is $I_0 = I_C + mr^2 = \frac{mL^2}{12} + m\left(\frac{L}{4}\right)^2 = \frac{7}{48}\ mL^2$

$$\frac{7}{48}\ mL^2\ \ddot{\theta} + \frac{1}{16}\ CL^2\ \dot{\theta} + \frac{12}{16} KL^2\ \theta = 0$$

As we know that for critical dumping, the root of the quadratic equation should be real and equal.

$$\therefore\ \ B^2 - 4AC = 0$$

$$\left(\frac{1}{16}\ CL^2\right)^2 - 4\left(\frac{7}{48}\ mL^2\right)\left(\frac{12}{16} KL^2\right) = 0$$

$$C = \sqrt{4\left(\frac{7}{1}\ m\right)\left(\frac{4}{1} K\right)} = 4\sqrt{7km}$$

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

37. 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. 0.17

Sol. Total no. of parts = 15

P[defective(p)] = 0.05

P[non-defective(q)]

= 1 – 0.05 = 0.95

P[at least 2 defective] = 1 – [P(no defective)+P(1 defective)]

Using the binomial distribution,

P[at least 2 defective]

= 1 – [$^{15}C_0 p^0 q^{15}$ + $^{15}C_1 p^1 q^{14}$]

= 1 – [$0.05^0 0.95^{15}$

+ 15$\times 0.05 \times 0.95^{14}$]

= 1 – [0.4639 + 0.3657]

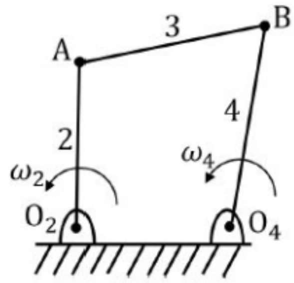
= 1 – 0.8296 = 0.1704

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

$O_2O_4 = O_2A = L,$

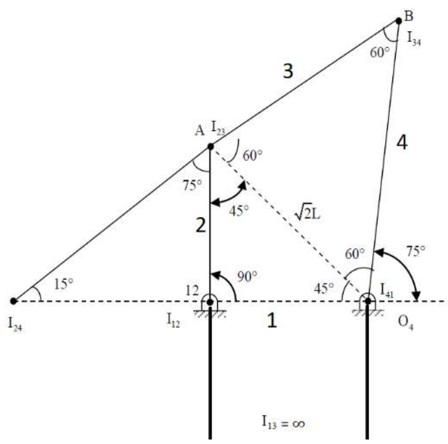
$AB = O_4B \quad \sqrt{2}L.$

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. 0.79

Sol. Using Instantaneous center method



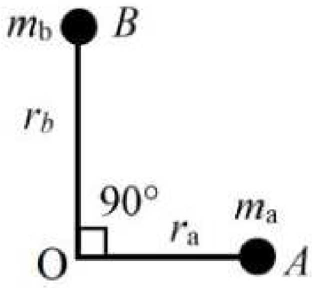
$$I_{24}I_{12}\omega_2 = I_{24}I_{41}\omega_4$$

$$I_{24}I_{12} = L\tan 75^o \ \ (\text{from } \Delta\, I_{12}I_{23}I_{24})$$

$$I_{24}I_{41} = L + L\tan 75^o$$

$$\therefore \frac{\omega_4}{\omega_2} = \frac{I_{24}I_{12}}{I_{24}I_{41}} = \frac{L\tan 75^o}{L + L\tan 75^o} = 0.788$$

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 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 placed at a radius of 200 mm is __________ kg (round off to two decimal places).



Ans. 41.23

Sol. Let the balance mass be m

$$\sum F_x = m_A r_A \cos 0° + m_B r_B \cos 90°$$

$+ mr\cos\theta = 0$ -----(1)

$$\sum F_y = m_A r_A \sin 0° + m_B r_B \sin 90°$$

$+ mr\sin\theta = 0$------ (2)

From (1),

$$mr\cos\theta = -[m_A r_A \cos 0° + m_B r_B \cos 90°]$$

Or, $mr\cos\theta = -[10 \times 200] = -2000$

From (2),

$$mr\sin\theta = -[m_A r_A \sin 0 + m_B r_B \sin 90°]$$

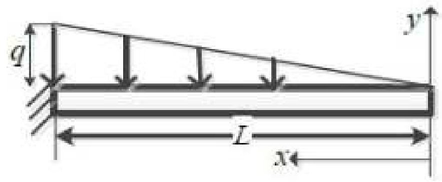
Or, $mr\sin\theta = -[20 \times 400] = -8000$

Using $\sqrt{(mr\cos\theta)^2 + (mr\sin\theta)^2} = mr$

$$= \sqrt{2000^2 + 8000^2} = 8246.21$$

Now, since the radius of the balance mass is 200mm, therefore $m = {}^{8246.21}/_{200} = 41.23\text{kg}$

40. 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. $\dfrac{qL^4}{60EI}$ B. $\dfrac{qL^4}{30EI}$

C. $\dfrac{qL^4}{10EI}$ D. $\dfrac{qL^4}{15EI}$

Ans. B

Sol. The maximum deflection of the cantilever beam subjected to uniformly varying load (UVL) is given by $\dfrac{qL^4}{30EI}$

41. Given a vector

$\vec{u} = \dfrac{1}{3}\left(-y^3\hat{i} + x^3\hat{j} + z^3\hat{k}\right)$ 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 $\int\left(\nabla \times \vec{u}\right) \bullet \hat{n}\, dS$ evaluated on the curved surface of the hemisphere S is

A. π B. $\dfrac{\pi}{3}$

C. $\dfrac{\pi}{2}$ D. $-\dfrac{\pi}{2}$

Ans. C

Sol. Hemisphere

($x^2 + y^2 + z^2 = 1; z \geq 0$)

To find the integration of the given expiration, it is easy if we are using the stoke's theorem. Surface integral will become line integral.

$$\int(\nabla \times \vec{u}) \bullet \hat{n} dS = \int \vec{u} \bullet dr$$

Now, putting the value of u in the above equation.

$$\int (\nabla \times \vec{u}) \bullet \hat{n} dS = \int_c \frac{1}{3}(-y^3 dx + x^3 dy + z^3 dz)$$

$$= \oint_c \frac{1}{3}(-y^3 dx + x^3 dy) \because Z = 0 \text{ at base circle}$$

$= \oint_c (y^2 dxdy + x^2 dxdy)$ [using green theorem]

$$= \iint (y^2 + x^2) dxdy$$

Now converting the above equation into polar coordinate

$x^2 + y^2 = r^2$

$$\int_{\theta=0}^{2\pi} \int_{r=0}^{1} r^2 \, r \, dr \, d\theta = \int_{\theta=0}^{2\pi} \left(\int_{r=0}^{1} r^3 dr \right) d\theta = \frac{\pi}{2}$$

42. 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 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).

Ans. 1.25

Sol. Draft = $(\Delta H)_{max} = \mu^2 R$

$$= 0.05^2 \times 300 = 0.75 mm$$

Hence, final thickness of the sheet = 2 – 0.75 = 1.25mm

43. 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, 9 kg

C. 1 kg only D. 1 kg, 6 kg

Ans. D

Sol: Conservation of momentum gives $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1 = 3kg$, $u_1 = 4m/s$, $m_2 = m\ kg$,

$$u_2 = 0$$

Substituting in the above equation,

$$3 \times 4 + m \times 0 = 3 \times v_1 + m \times v_2$$

Or, $12 = 3v_1 + mv_2$-------(1)

For perfectly-elastic impact,

$$e = \frac{v_2 - v_1}{u_1 - u_2} = 1$$

Or, $v_2 - v_1 = u_1 - u_2 = 4 m/s$----- (2)

Conservation of kinetic

energy gives

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

Or,

$$\frac{1}{2}3(4)^2 + 0 = 6 + \frac{1}{2}m_2v_2^2$$

Or, $mv_2^2 = 36$ ---------(3)

From equation (2), $v_1 = v_2 - 4$

Substituting in equation (1),

$$12 = 3(v_2 - 4) + mv_2$$

Or $12 = 3v_2 - 12 + mv_2$

Or $v_2(3 + m) = 24$

Or $v_2 = \frac{24}{3+m}$

Substituting in equation (3)

$$m\left(\frac{24}{3+m}\right)^2 = 36$$

$$576m = 36(3 + m)^2$$

$$\Rightarrow 16m = 9 + m^2 + 6m$$

$$m^2 - 10m + 9 = 0$$

On solving, we get

$$m = 1,9$$

Therefore, possible values of m are 1 kg and 9 kg.

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

A. > 1% and < 5%

B. < 0.1%

C. > 0.1% and < 1%

D. > 5%

Ans. C

Sol. f(x) = cos(x)

$\Rightarrow$ f′(x) = -sin(x)

$= -\sin(\pi/6) = -0.5$ (exact value)

Approximate value

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

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

$$\cos(x+h) = \cos x \cos h - \sin x \sin h$$

$$\cos(x-h) = \cos x \cos h + \sin x \sin h$$

So,

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

$$= \frac{-2\sin x \sin h}{2h} = \frac{-\sin x \sin h}{h}$$

Or, $f'(x) = \frac{-\sin\left(\frac{\pi}{6}\right)\sin(0.1)}{0.1}$

$$= \frac{-0.5 \times 0.0998}{0.1} = -0.4992$$

So, percentage error

$= \frac{-0.5-(-0.4992)}{-0.5} \times 100 = 0.166$

45. 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 frontal area may be assumed to be constant).

Ans. 22

Sol. The power needed to overcome the aerodynamic drag is given by $F_d \times V$

Where, F_d is the drag force given by

$$F_d = {}^1\!/_2\, C_d \rho A V^2$$

For the power to remain same in both the cases of windows closed and open, then

$$(F_d \times V)_{\text{windows closed}} = (F_d \times V)_{\text{windows open}}$$

Or,

$$\left({}^1\!/_2\, C_d \rho A V^3\right)_{\text{windows closed}} = \left({}^1\!/_2\, C_d \rho A V^3\right)_{\text{windows open}}$$

Or, $0.1 \times 44^3 = 0.8 \times V^3$

Or V = 22 km/h

46. 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).

Ans. 8.106

Sol. Diameter

$= 2 \times \text{radius of blade} = 2 \times 50 = 100\text{mm} = 0.1\text{ m}$

$$u = \frac{\pi DN}{60} = \frac{\pi \times 0.1 \times 3000}{60} = 15.71\text{ m/sec}$$

Now, power = mass flow rate × u^2

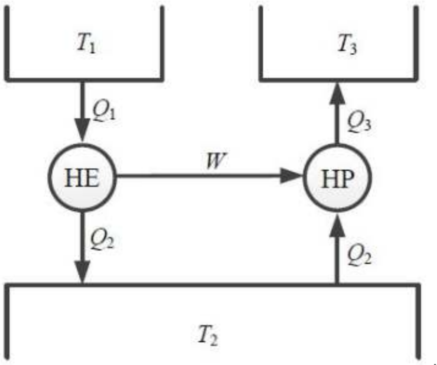
$$\Rightarrow 2000 = \dot{m} \times (15.71)^2$$

Or, $\dot{m} = 8.106$

47. 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. OCP = 1 + η

C. COP = η^{-1}

D. COP = η^{-1} -1

Ans. C

Sol. For heat engine, $\eta = \frac{W}{Q_1}$

For Heat engine, $COP = \frac{Q_3}{W}$

Energy balance for Heat engine gives $Q_2 = Q_1 - W$

And energy balance for Heat pump gives $Q_3 = Q_2 + W = Q_1 - W + W = Q_1$

Hence, $COP = \frac{Q_1}{W} = \frac{1}{\eta} = \eta^{-1}$

48. Three sets 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 ____________.

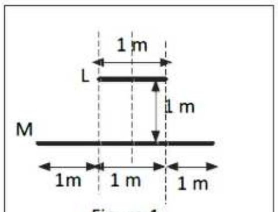


Figure 1

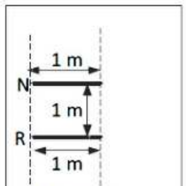


Figure 2

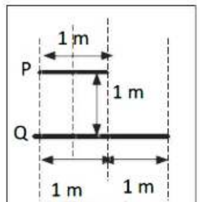


Figure 3

Ans. 0.6

Sol. $F_{PQ} = F_{NR} + \frac{F_{LM} - F_{NR}}{2} = 0.4 + \frac{0.8 - 0.4}{2} = 0.6$

49. 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 Cc = 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).

Ans.

Sol. Given data

$T_{h_i} = 100°C,\ T_{c_i} = 15°C,\ T_{c_e} = 45°C$

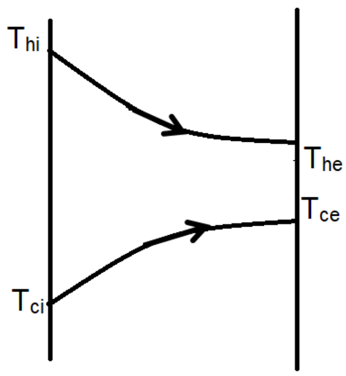
$C_h = 2000 W/K,\ C_c = 1200 W/K$

Using the energy balance equation for the heat exchanger

$$C_h(T_{h_i} - T_{h_e}) = C_c(T_{c_e} - T_{c_i})$$

$$\Rightarrow 2000(100 - T_{h_e}) = 1200(45 - 15)$$

$$\Rightarrow T_{h_e} = 82°C$$



$$\Delta T_i = T_{h_i} - T_{c_i} = 100 - 15 = 85°C$$

$$\Delta T_e = T_{h_e} - T_{c_e} = 82 - 45 = 37°C$$

$$LMTD = \frac{\Delta T_i - \Delta T_e}{\ln\frac{\Delta T_i}{\Delta T_e}} = \frac{85 - 37}{\ln\frac{85}{37}} = 57.71°C$$

50. 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. $y=\frac{C_1}{x^2}+C_2x+4$

B. $y=C_1x^2+C_2\,x+4$

C. $y=C_1\,x^2+C_2\,x+2$

D. $y=\frac{C_1}{x^2}+C_2x+2$

Ans. D

Sol. Given differential equation

$$(D(D-1)-2D+2)y=4 \text{ where } x=e^z$$

Auxiliary equation,

$$(D-2)(D-1)=0$$

$D=1,2$

$CF = C_1\,e^{1x}+C_2\,e^{2x}$

$PI = \frac{4}{(D-2)(D-1)} = 2$

$Y = CF + PI$

$\therefore y = C_1\,e^{1x}+C_2\,e^{2x}+2$

51. 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 and the surroundings. Assuming an ambient temperature of 300 K, the irreversibility rate of the system is _________kW (round off to two decimal places).

Ans. 2.1

Sol. The entropy generation (S_{gen}) is given by rise in entropy rise of the system (Since no heat interaction is involved)

So, entropy generation (S_{gen})

$= \dot{m}\times\text{specific entropy} = 1\times 0.007 = 0.007\text{ kW/K}$

Now, according to Gouy Stodola theorem,

Irreversibility =

$$T_o\times S_{gen} = 300\times 0.007 = 2.1\text{kW}$$

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).

Ans. 0.74

Sol. uncut chip thickness

(t) = 0.125 mm

Cut chip thickness (t_c) = 0.22 mm

So, ship thickness ratio

$=\frac{t}{t_c}=\frac{0.125}{0.22}=0.568$

Rake angle (α) = 10°

$$\tan\phi=\frac{r\cos\alpha}{1-r\sin\alpha}=\frac{0.568\times\cos 10}{1-0.568\times\sin 10}=0.6206$$

Or shear angle (ϕ) = 31.82°

According to Merchant's theory,

we have

$$2\phi+\beta-\alpha=\frac{\pi}{2}$$

So, $\beta=90°-63.64+10=36.36°$

Now,

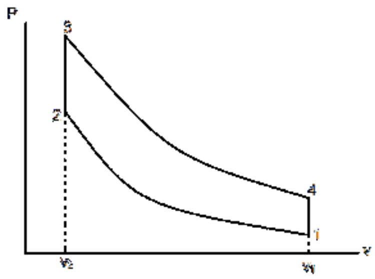
$$\tan\beta=\mu\text{ (coefficient of friction)}$$

Therefore, coefficient of friction $= \tan 36.36° = 0.74$

53. 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 γ = 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).

Ans. 708.8

Sol.



Given data

P_1 = 100kPa, T_1 = 300K, mep = 1000 kPa, $\gamma = 1.4$, efficiency $(\eta) = 0.5$, R = 0.287 kJ/kg-K

Using $P_1V_1 = RT_1$

$V_1 = \frac{0.287 \times 300}{100} = 0.861 \text{m}^3/\text{kg}$

Efficiency $(\eta) = 1 - \frac{1}{(r)^{\gamma-1}}$ where, r is the compression ratio = V_1/V_2

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

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

Or, r = 5.657

V_1/V_2 = 5.657

$\Rightarrow V_2 = 0.1522 \text{ m}^3/\text{kg}$

Swept volume = V_1 – V_2 = 0.861 – 0.1522 = 0.7088 m^3/kg

Went = Swept volume $\times$ mep

= 0.7088 × 1000 = 708.8 kJ/kg

54. 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).

Ans. 274.89

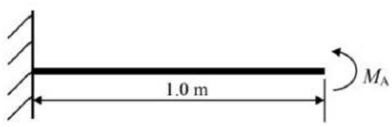
Sol. $\text{MRR} = \frac{\pi d^2}{4} \times \text{feed} \times \text{rev per sec} = \frac{\pi(10)^2}{4} \times 0.25 \times \frac{1200}{60} = 125\pi \text{ mm}^3$

Specific energy = 0.7 Nm/mm^3

So, power required for drilling

$= 0.7 \times 125\pi = 274.89\text{W}$

55. 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 one decimal place).



Ans. 2.5

Sol. When the cantilever beam is subjected to moment at the free end, then the deflection at the free end is given by

$$y_{(\text{free end})} = \frac{ML^2}{2EI}$$

So,

$$y_{(\text{free end})} = \frac{1 \times 1^2}{2 \times 200} = 2.5 \times 10^{-3}\text{m} = 2.5 \text{ mm}$$

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