General Aptitude.

Q.1 to Q.5 Carry One Mark Each.

Question 1

After playing _________ hours of tennis, I am feeling _________ tired to walk back.

(A) too / too (B) too / two (C) two / two (D) two / too

Ans. **(D)**

Sol. In first filler we need to mention number so option (A) and (B) are eliminated and in second filler we are getting the sense of exhausted, so it should be 'too'

Hence, the correct option is (D).

Question 2

The average of the monthly salaries of M, N and S is Rs. 4000. The average of the monthly salaries of N, S and P is Rs. 5000. The monthly salary of P is Rs. 6000.

What is the monthly salary of M as a percentage of the monthly salary of P?

(A) 50% (B) 75% (C) 100% (D) 125%

Ans. **(A)**

Sol. **Given :**

Average salary of M,N,S = Rs. 4000

Average salary of N,S,P = Rs 5000

Monthly salary of P = Rs. 6000

$$\frac{M+N+S}{3}=4000$$

$$\frac{N+S+P}{3}=5000$$

$$M+N+S=12000$$

$$N+S+P=15000$$

Monthly salary of $P=6000$

$$N+S+6000=15000$$

$$N+S=9000$$

$$M+9000=12000$$

$$M=3000$$

Percentage salary of M with respect to

$$=\frac{3000}{6000}\times 100\%=50\%$$

Hence, the correct option is (A).

Question 3

A person travelled 80 km in 6 hours. If the person travelled the first part with a uniform speed of 10 kmph and the remaining part with a uniform speed of 18 kmph.

What percentage of the total distance is travelled at a uniform speed of 10 kmph?

(A) 28.25 (B) 37.25 (C) 43.75 (D) 50.00

Ans. (C)

Sol. Given Total distance covered by a person = 80 km

Total time taken by that person = 6 hours

Speed of first part of journey = 10 kmph

Speed of second part of journey = 18 kmph

Assume, time taken for 1^{st} part = t hrs

Time taken for 2^{nd} part = (6-t) hrs

Distance = Speed × Time

$$80 = 10t + 18(6-t)$$

$$80 = 10t + 108 - 8t$$

$$-28 = -8t$$

$$t = 3.5 \text{ hrs}$$

Distance travelled with speed 10 kmph

$$10 \times 3.5 = 35 \text{ km}$$

Percentage of the total distance is

Travelled at a uniform speed of 10 kmph

$$= \frac{35}{80} \times 100 = 43.75\%$$

Hence, the correct option is (C).

Question 4

Four girls P, Q, R and S are studying languages in a University. P is learning French and Dutch. Q is learning Chinese and Japanese. R is learning Spanish and French. S is learning Dutch and Japanese.

Given that: French is easier than Dutch; Chinese is harder than Japanese; Dutch is easier than Japanese, and Spanish is easier than French.

Based on the above information, which girl is learning the most difficult pair of languages?

(A) P (B) Q (C) R (D) S

Ans. (B)

Sol. Given :

P is learning French and Dutch

Q is learning Chinese and Japanese

R is learning Spanish and French

S is learning Dutch and Japanese

French < Dutch … (i)

Chinese > Japanese … (ii)

Japanese > Dutch … (iii)

French > Spanish … (iv)

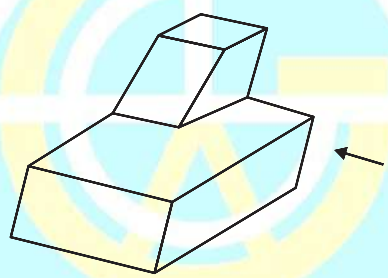
By equation (i), (ii), (iii) and (iv)

Chinese > Japanese > Dutch > French > Span according to the difficulty level arrangement

Girl Q is learning most difficult pair of languages, which is Chinese and Japanese.

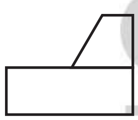
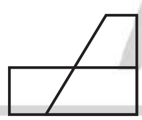
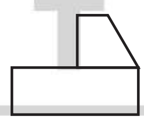
Hence, the correct option is (B).

Question 5



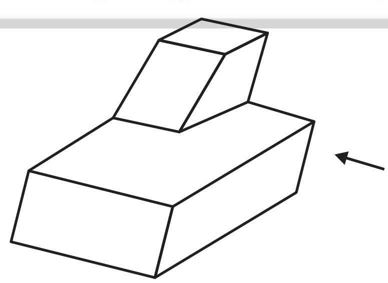
A block with a trapezoidal cross-section is placed over a block with rectangular cross section as shown above.

Which one of the following is the correct drawing of the view of the 3D object as viewed in the direction indicated by an arrow in the above figure?

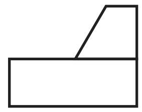
(A)  (B)  (C)  (D) 

Ans. **(A)**

Sol. Given :



The correct drawing of the view of the 3D object as viewed in the direction indicated by an arrow,



Hence, the correct option is (A).

Q.6 to Q. 10 Carry Two Marks Each.

Question 6

Humans are naturally compassionate and honest. In a study using strategically placed wallets that appear "lost", it was found that wallets with money are more likely to be returned than wallets without money. Similarly, wallets that had a key and money are more likely to be returned than wallets with the same amount of money alone. This suggests that the primary reason for this behavior is compassion and empathy.

Which one of the following is the CORRECT logical inference based on the information in the above passage?

(A) Wallets with a key are more likely to be returned because people do not care about money

(B) Wallets with a key are more likely to be returned because people relate to suffering of others

(C) Wallets used in experiments are more likely to be returned than wallets that are really lost

(D) Money is always more important than keys

Ans. **(B)**

Sol. Option (B) is correct logical inference as wallets with a key are more likely to be returned because people relate to suffering of others as mentioned in the passage "the primary reason for this behavior is compassion and empathy".

Hence, the correct option is (B).

Question 7

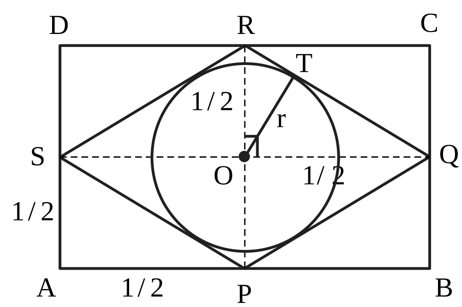
A rhombus is formed by joining the midpoints of the sides of a unit square.

What is the diameter of the largest circle that can be inscribed within the rhombus?

(A) $\frac{1}{\sqrt{2}}$ (B) $\frac{1}{2\sqrt{2}}$ (C) $\sqrt{2}$ (D) $2\sqrt{2}$

Ans. **(A)**

Sol. Let $ABCD$ be the square of unit length and P, Q, R, S be midpoints of AB, BC, CD, DA respectively



Let O be centre of circle

$$OR = OQ = \frac{1}{2}\text{ units}$$

$$SP = \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2} \text{ (in } \Delta SAP\text{)}$$

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

$$SP = PQ = RQ = PS \text{ (rhombus)}$$

Area of $\Delta ORQ = \frac{1}{2} OROQ$

$$= \frac{1}{2} OT \times RQ$$

$$\frac{1}{2}\cdot\frac{1}{2}\cdot\frac{1}{2} = \frac{1}{2} \times r \times RQ$$

$$r = \frac{1}{2\sqrt{2}}$$

Diameter $= 2r = \frac{1}{\sqrt{2}}$

Hence, the correct option is (A).

Question 8

An equilateral triangle, a square and a circle have equal areas.

What is the ratio of the perimeters of the equilateral triangle to square to circle?

(A) $3\sqrt{3} : 2 : \sqrt{\pi}$ (B) $\sqrt{(3\sqrt{3})} : 2 : \sqrt{\pi}$

(C) $\sqrt{(3\sqrt{3})} : 4 : 2\sqrt{\pi}$ (D) $\sqrt{(3\sqrt{3})} : 2 : 2\sqrt{\pi}$

Ans. **(B)**

Sol. Let, equilateral Δ of side a

square of side b

radius of circle = r

$$\frac{\sqrt{3}a^2}{4} = b^2 = \pi r^2$$

$$b = \left(\frac{\sqrt{\sqrt{3}}}{2}\right)a$$

$$r = \left(\sqrt{\frac{\sqrt{3}}{\pi}}\right)\frac{1}{2}a$$

Ratio of perimeters, $3a : 4b : 2\pi r$

$$= 3a : \frac{4\sqrt{\sqrt{3}}a}{2} : 2\pi\sqrt{\frac{\sqrt{3}}{\pi}} \times \frac{1}{2}a$$

$$= 3 : 2\sqrt{\sqrt{3}} : \sqrt{\sqrt{3}\pi}$$

$$= 3\sqrt{\sqrt{3}} : 2\sqrt{3} : \sqrt{3}\pi$$

$$= \frac{3\sqrt{\sqrt{3}}}{\sqrt{2}} : 2 : \pi = \sqrt{3\sqrt{3}} : 2 : \sqrt{\pi}$$

Hence, the correct option is (B).

Question 9

Given below are three conclusions drawn based on the following three statements.

Statement 1: All teachers are professors.

Statement 2: No professor is a male.

Statement 3: Some males are engineers.

Conclusion I: No engineer is a professor.

Conclusion II: Some engineers are professors.

Conclusion III: No male is a teacher.

Which one of the following options can be logically inferred?

(A) Only conclusion III is correct

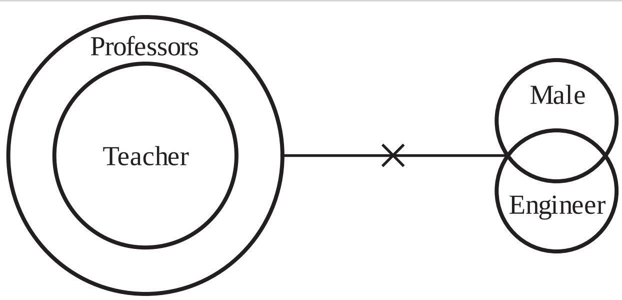
(B) Only conclusion I and conclusion II are correct

(C) Only conclusion II and conclusion III are correct

(D) Only conclusion I and conclusion III are correct

Ans. **(A)**

Sol. Given :



Conclusion I. No engineer is professor

As no information is provided for some part of engineers, they can be part of professors and cannot be part of professors.

Hence, it can be inferred from statement.

Conclusion II. Some engineers are professor.

As no information is provided for some part of engineers, they can be part of professors and cannot be part of professors.

Hence, it can be inferred from statement.

Conclusion III. No male is a teacher.

Can be inferred from statement as we can see in the diagram.

All part of teacher is inside of professors and no professor is male. Hence teachers are also not male.

Hence, the correct option is (A).

Question 10

In a 12-hour clock that runs correctly, how many times do the second, minute, and hour hands of the clock coincide, in a 12-hour duration from 3 PM in a day to 3 AM the next day?

(A) 11 (B) 12 (C) 144 (D) 2

Ans. (A)

Sol. In a 12 hour duration second, minute and hour hands of clock can be coincide, 11 times.

In every 1 hour hands of a clock will coincide one time and in 12 hour period hands of a clock will coincide only for 11 time as between 11 to 1 hands will be coincided only for 1 time at exactly 12.

Hence, the correct option is (A).

Technical Section

Question 1

The limit

$p=\lim\limits_{x\to\pi}\left(\dfrac{x^2+ax+2\pi^2}{x-\pi+2\sin x}\right)$ has a finite value for a real α. The value of α and the corresponding limit p are

(A) $\alpha=-3\pi,$ and $p=\pi$ (B) $\alpha=-2\pi,$ and $p=2\pi$

(C) $\alpha=\pi,$ and $p=\pi$ (D) $\alpha=2\pi,$ and $p=3\pi$

Ans. (A)

Sol. Given : The limit $p=\lim\limits_{x\to\pi}\left(\dfrac{x^2+ax+2\pi^2}{x-\pi+2\sin x}\right)$

It has finite value for real a.

$$p=\frac{\pi^2+a\pi+2\pi^2}{\pi-\pi+2\sin\pi}$$

$$p=\frac{3\pi^2+a\pi}{0+2\times 0}$$

$$p=\frac{3\pi^2+a\pi}{0}$$

It becomes ∞ but according to question the limit has finite value.

That means, $3\pi^2+a\pi$ should be zero to become $\left(\frac{0}{0}\right)$ form, so that we can apply L' hospital rule.

$$3\pi^2+a\pi=0$$

$$a\pi=-3\pi^2$$

$$a=-3\pi$$

Now, putting the value $a=-3\pi$,

$$p=\lim_{x\to\pi}\frac{x^2+(-3\pi)x+2\pi^2}{x-\pi+2\sin x}$$

$$p=\lim_{x\to\pi}\frac{x^2-3\pi x+2\pi^2}{x-\pi+2\sin x}=\left(\frac{0}{0}\right)\text{ form}$$

We can apply L' hospital rule,

$$p=\lim_{x\to\pi}\frac{2x-3\pi}{1+2\cos x}=\frac{2x-3\pi}{1+2\cos x}$$

$$p=\frac{-\pi}{1+2\times(-1)}$$

$$p=\frac{-\pi}{1-2}$$

$$p=\pi$$

Hence, the correct option is (A).

Question 2

Solution of $\nabla^2 T=0$ in a square domain $(0<x<1 \text{ and } 0<y<1)$ with boundary conditions:

$T(x,0)=x;\ T(0,y)=y;\ T(x,1)=1+x;\ T(1,y)=1+y$ is

(A) $T(x,y)=x-xy+y$ (B) $T(x,y)=x+y$

(C) $T(x,y)=-x+y$ (D) $T(x,y)=x+xy+y$

Ans. **(B)**

Sol. **Given :** Laplace equation $\nabla^2 T=0$, $(0<x<1,\ 0<y<1)$

$$T(x,0)=x,\ T(0,y)=y,\ T(x,1)=1+x,\ T(1,y)=1+y$$

Solution of Laplace equation is given by,

$$T(x,y) = (C_1x + C_2)(C_3y + C_4) \quad \ldots\text{(i)}$$

Using boundary condition,

$$T(x,0) = (C_1x + C_2)(C_4) = x \quad \ldots\text{(ii)}$$

$$T(0,y) = C_2(C_3y + C_4) = y \quad \ldots\text{(iii)}$$

$$T(x,1) = (C_1x + C_2)(C_3 + C_4) = 1 + x \quad \ldots\text{(iv)}$$

$$T(1,y) = (C_1 + C_2)(C_3y + C_4) = 1 + y \quad \ldots\text{(v)}$$

By solving equations (ii), (iii), (iv) and (v),

$$C_1 = 1,\ C_3 = 1,\ C_2 = 0 \text{ and } C_4 = 0$$

Therefore, the solution is given by equation (i),

$$T(x,y) = x + y$$

Hence, the correct option is (B).

Question 3

Given a function $\varphi = \frac{1}{2}(x^2 + y^2 + z^2)$ in three-dimensional Cartesian space, the value of the surface integral

$$\oiint_S \hat{\boldsymbol{n}} \cdot \nabla\varphi dS,$$

where S is the surface of a sphere of unit radius and $\hat{\boldsymbol{n}}$ is the outward unit normal vector on S, is

(A) 4π (B) 3π (C) $4\pi/3$ (D) 0

Ans. **(A)**

Sol. **Given :** A function $\psi(x,y,z) = \frac{1}{2}(x^2 + y^2 + z^2)$ in three dimensional cartesian space.

Surface integral,

$$I = \oiint_S \hat{n} \cdot \nabla\psi\, ds$$

where, S is the surface of sphere of unit radius and $\hat{n}$ is the outward unit normal vector on S.

$$\nabla\psi = \text{Grad}\,\psi = \left(\hat{i}\frac{\delta}{\delta x} + \hat{j}\frac{\delta}{\delta y} + \hat{k}\frac{\delta}{\delta z}\right)\psi$$

$$\nabla\psi = \left(\hat{i}\frac{\delta}{\delta x} + \hat{j}\frac{\delta}{\delta y} + \hat{k}\frac{\delta}{\delta z}\right)\left[\frac{1}{2}(x^2 + y^2 + z^2)\right]$$

$$\nabla\psi = \frac{1}{2}\left[\hat{i}\frac{\delta}{\delta x}(x^2+y^2+z^2)+\hat{j}\frac{\delta}{\delta y}(x^2+y^2+z^2)+\hat{k}\frac{\delta}{\delta z}(x^2+y^2+z^2)\right]$$

$$\nabla\psi = x\hat{i}+y\hat{j}+z\hat{k}$$

then, surface integral $I = \oiint_S \hat{n}\cdot(x\hat{i}+y\hat{j}+z\hat{k})\,ds$

By divergence theorem,

$$\oiint_S \vec{A}\,\hat{n}\,ds = \iiint_V (\vec{\nabla}\cdot\vec{A})\,dv$$

$$\vec{\nabla}\cdot\vec{A} = \text{Div}(\vec{A}) = \left(\hat{i}\frac{\delta}{\delta x}+\hat{j}\frac{\delta}{\delta y}+\hat{k}\frac{\delta}{\delta z}\right)(x\hat{i}+y\hat{j}+z\hat{k})$$

$$\vec{\nabla}\cdot\vec{A} = \text{Div}(\vec{A}) = 1+1+1=3$$

$$I = \iiint_V 3\,dv$$

$$I = 3\iiint_V dv$$

$$I = 3V$$

Volume of sphere, $V = \frac{4}{3}\pi r^3$ (with $r=1$)

$$I = 3\times\frac{4}{3}\pi\times 1^3$$

$$I = \frac{3\times 4}{3}\pi$$

$$I = 4\pi$$

Hence, the correct option is (A).

Question 4

The Fourier series expansion of x^3 in the interval $-1\le x<1$ with periodic continuation has

(A) Only sine terms

(B) Only cosine terms

(C) Both sine and cosine terms

(D) Only sine terms and a non-zero constant

Ans. **(A)**

Sol. **Given :** Function $f(x)=x^3$; $\quad -1\le x<1$

The above function $f(x)$ is odd.

We know that, odd function contains only odd terms,

$$f(x)=\frac{a_0}{2}+\sum_{n=1}^{\infty}\left[a_n\cos\frac{n\pi x}{T}+b_n\sin\frac{n\pi x}{T}\right]$$

a_0 and a_n will be zero.

Therefore, the given function $f(x)$ contains only sine term.

Hence, the correct option is (A).

Question 5

If $A=\begin{bmatrix}10 & 2k+5\\ 3k-3 & k+5\end{bmatrix}$ is a symmetric matrix, the value of k is ___________.

(A) 8 (B) 5 (C) -0.4 (D) $\frac{1+\sqrt{1561}}{12}$

Ans. **(A)**

Sol. **Given :** Matrix $A=\begin{bmatrix}10 & 2K+5\\ 3K-3 & K+5\end{bmatrix}$ is symmetric matrix.

A matrix $[A]=\begin{bmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\end{bmatrix}$ is to be symmetric if $[A]=[A^T]$ or $a_{12}=a_{21}$

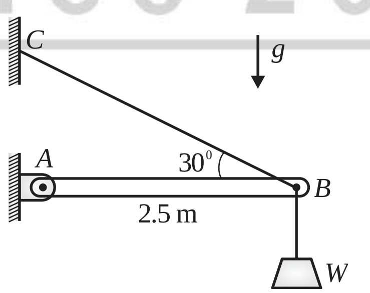
That means,

$$2K+5=3K-3$$
$$5+3=3K-2K$$
$$K=8$$

Hence, the correct option is (A).

Question 6

A uniform light slender beam AB of section modulus EI is pinned by a frictionless joint A to the ground and supported by a light inextensible cable CB to hang a weight W as shown. If the maximum value of W to avoid buckling of the beam AB is obtained as $\beta\pi^2 EI$, where π is the ratio of circumference to diameter of a circle, then the value of β is

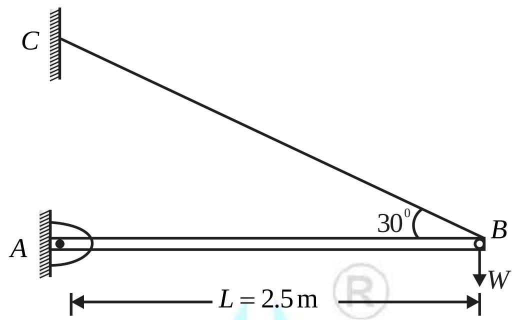


(A) 0.0924 m^{-2} (B) 0.0713 m^{-2}

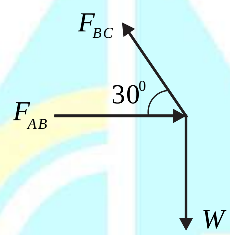
(C) 0.1261 m^{-2} (D) 0.1417 m^{-2}

Ans. (A)

Sol.



F.B.D. at point B



$$+\uparrow \sum F_V = 0$$

$$F_{BC} \sin 30^0 = \text{W}$$

$$F_{BC} = 2\text{ W} \qquad \ldots \text{(i)}$$

$$\rightarrow + \sum F_H = 0$$

$$F_{AB} = F_{BC} \cos 30^0$$

$$F_{AB} = 2W \times \frac{\sqrt{3}}{2}$$

$$F_{AB} = \sqrt{3}\text{ W} \qquad \ldots \text{(ii)}$$

Buckling load

$$P_C = \frac{\pi^2 EI}{L_C^2} = \frac{\pi^2 EI}{2.5^2} \qquad \ldots \text{(iii)}$$

From equation (ii) and (iii)

$$\sqrt{3}\text{ W} = \frac{\pi^2 EI}{2.5^2}$$

$$\sqrt{3} \times \beta \pi^2 EI = \frac{\pi^2 EI}{2.5^2}$$

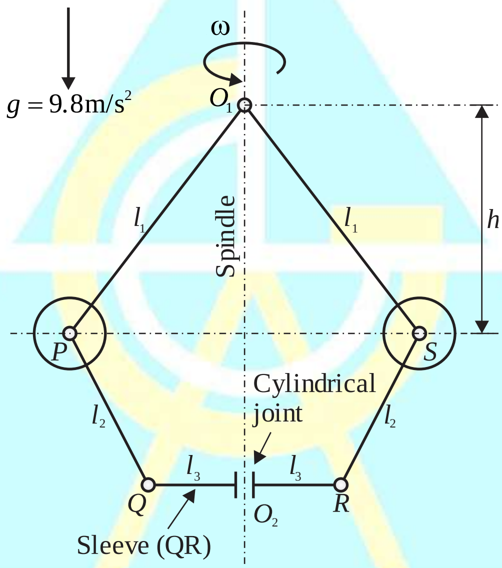
$$\beta = \frac{1}{\sqrt{3} \times 2.5^2}$$

$$\beta = 0.092$$

Hence, the correct option is (A).

Question 7

The figure shows a schematic of a simple Watt governor mechanism with the spindle O_1O_2 rotating at an angular velocity ω about a vertical axis. The balls at P and S have equal mass. Assume that there is no friction anywhere and all other components are massless and rigid. The vertical distance between the horizontal plane of rotation of the balls and the pivot O_1 is denoted by h. The value of h = 400 mm at a certain ω. If ω is doubled, the value of h will be __________ mm.



(A) 50 (B) 100 (C) 150 (D) 200

Ans. **(B)**

Sol. $\omega^2 = \frac{g}{h}$ for watt governor

$$(\omega \propto N)$$

$$N^2 = \frac{g}{h}$$

$$\omega_1^2 = \frac{g}{h}$$

$$h_1 = 400 \qquad \text{Given}$$

$$\frac{\omega_1^2 = \frac{g}{h_1}}{\omega_2^2 = \frac{g}{h_2}}$$

$$\omega_2 = 2\omega_1$$

$$\frac{\omega_1}{4\omega_1} = \frac{g}{h_1} \times \frac{h_2}{g}$$

$$\frac{400}{4} = h_2$$

$$h_2 = 100$$

Hence, the correct option is (B).

Question 8

A square threaded screw is used to lift a load ***W*** by applying a force ***F***. Efficiency of square threaded screw is expressed as

(A) The ratio of work done by ***W*** per revolution to work done by ***F*** per revolution

(B) ***W/F***

(C) ***F/W***

(D) The ratio of work done by ***F*** per revolution to work done by ***W*** per revolution

Ans. **(A)**

Sol. **Given :**

Load $= W$

Applied force $= F$

The efficiency of square thread salent is

$$\eta = \frac{\text{Work done by load per revolution}}{\text{Work done by force per revolution}}$$

Hence, the correct option is (A).

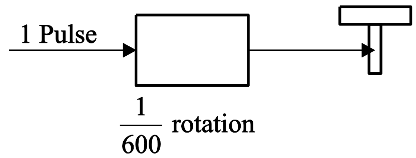
Question 9

A CNC worktable is driven in a linear direction by a lead screw connected directly to a stepper motor. The pitch of the lead screw is 5 mm. The stepper motor completes one full revolution upon receiving 600 pulses. If the worktable speed is 5 m/minute and there is no missed pulse, then the pulse rate being received by the stepper motor is

(A) 20 kHz (B) 10 kHz (C) 3 kHz (D) 15 kHz

Ans. **(B)**

Sol.



$$\frac{1}{600} \times Pitch = \text{BLU}$$

$$\frac{5}{600}\text{ mm} = \text{BLU}$$

$\therefore$ $$\frac{5}{600}\text{ mm} \rightarrow 1\text{ pulse}$$

Or, $$1\text{ mm} \rightarrow \frac{1}{5/600} = \frac{600}{5}\text{ pulse}$$

$$5000\frac{\text{mm}}{\text{min}} \rightarrow \frac{600 \times 5000}{5}\frac{\text{Pulse}}{\text{min}}$$

$$= \frac{600 \times 5000}{5} \times \frac{1}{60}\text{ pulse/sec}$$

$$= 10,000\text{ Hz} = 10\text{ kHz}$$

Hence, the correct option is (B).

Question 10

The type of fit between a mating shaft of diameter $25.0^{+0.010}_{-0.010}$ mm and a hole of diameter $25.015^{+0.015}_{-0.015}$ mm is __________.

(A) Clearance (B) Transition

(C) Interference (D) Linear

Ans. (B)

Sol. Shaft $= 25^{+0.01}_{-0.01}$ mm Hole $= 25.015^{+0.015}_{-0.015}$

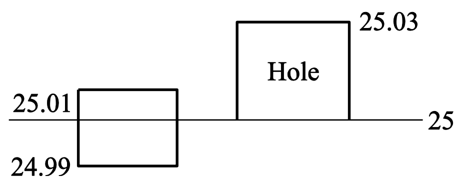
For shaft, Upper limit $= 25.01$

Lower limit $= 24.99$

For hole

Upper limit $= 25.03$

Lower limit $= 25$



It is a transition fit.

Hence, the correct option is (B).

Question 11

In a linear programming problem, if a resource is not fully utilized, the shadow price of that resource is

(A) Positive (B) Negative (C) Zero (D) Infinity

Ans. **(C)**

Sol. In linear programming problem, if a resource is not fully utilized, the shadow price of that resource will be zero.

Hence the correct option is (C).

Question 12

Which one of the following is **NOT** a form of inventory?

(A) Raw materials (B) Work-in-process materials

(C) Finished goods (D) CNC Milling Machines

Ans. **(D)**

Sol. CNC machines are not a form of inventory

Hence the correct option is (D).

Question 13

The Clausius inequality holds good for

(A) any process (B) any cycle

(C) only reversible process (D) only reversible cycle

Ans. **(B)**

Sol. Clausius inequality

$$\oint \frac{S_Q}{T} \leq 0$$

Is hold good for any cycle hence the correct option is (B).

Hence, the correct option is (B).

Question 14

A tiny temperature probe is fully immersed in a flowing fluid and is moving with zero relative velocity with respect to the fluid. The velocity field in the fluid is $\vec{V} = (2x)\hat{i} + (y+3t)\hat{j}$, and the temperature field in the fluid is $T = 2x^2 + xy + 4t$, where x and y are the spatial coordinates, and t is the time. The time rate of change of temperature recorded by the probe at ($x = 1$, $y = 1$, $t = 1$) is ________.

(A) 4 (B) 0 (C) 18 (D) 14

Ans. **(C)**

Sol.

$$\vec{V} = 2x\hat{i} + (y+3t)\hat{j}$$

$$T = 2x^2 + xy + 4t \quad \text{Find } \frac{d\gamma}{dt} \text{ at } x=1, \gamma=1, t=1$$

Using relation –

$$\frac{dT}{dt} = \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + U\frac{\partial T}{\partial y}$$

$$= 4 + 2(4+1) + (1+3)\times 1$$

$$= 4 + 10 + 4 = 18$$

Hence, the correct option is (C).

Question 15

In the following two-dimensional momentum equation for natural convection over a surface immersed in a quiescent fluid at temperature T_∞ (g is the gravitational acceleration, β is the volumetric thermal expansion coefficient, v is the kinematic viscosity, u and v are the velocities in x and y directions, respectively, and T is the temperature)

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = g\beta(T - T_\infty) + v\frac{\partial^2 u}{\partial y^2}$$, the term $g\beta(T-T_\infty)$ represents

(A) Ratio of inertial force to viscous force.
(B) Ratio of buoyancy force to viscous force.
(C) Viscous force per unit mass.
(D) Buoyancy force per unit mass.

Ans. **(D)**

Sol.

$$\frac{u\partial u}{\partial x} + \frac{v\partial u}{\partial y} = g\beta(T - T_\infty) + \partial\frac{\partial^2 u}{\partial y^2}$$

We know that

Buoyancy force, $F_B = m \times g\beta(T - T_\infty) = \rho L_C^3 g\beta(T - T_\infty)$

$$\frac{F_B}{\text{mass}} = \frac{\rho L_C^3\, g\beta(T - T_\infty)}{\rho L_C^3} = g\beta(T - T_\infty)$$

Hence, the correct option is (D).

Question 16

Assuming the material considered in each statement is homogeneous, isotropic, linear elastic, and the deformations are in the elastic range, which one or more of the following statement(s) is/are TRUE?

(A) A body subjected to hydrostatic pressure has no shear stress.

(B) If a long solid steel rod is subjected to tensile load, then its volume increases.

(C) Maximum shear stress theory is suitable for failure analysis of brittle materials.

(D) If a portion of a beam has zero shear force, then the corresponding portion of the elastic curve of the beam is always straight.

Ans. **(A & B)**

Sol. For homogeneous, isotropy & linear elastic.

(A) A body is subjected to hydrostatic pressure has no shear stress.

$\tau = 0$ (In case of hydrostatic loading)

(B) If a long solid rod is subjected to tensile load then volume increases.

$$\frac{\sigma_x + \sigma_y + \sigma_z}{E} \times (1 - 2\mu) = \varepsilon_v \qquad (\sigma_z = \sigma_y = 0) \qquad \text{.... (i)}$$

We know that the value of Possions ratio for elastic material is less than 0.5

From equation (i) The value of $\left[\frac{\sigma_x}{E}(1-2\mu)\right]$ is positive when $(\mu < 0.5)$ so, ε_v is also positive.

Hence, volume increases

Hence, the correct option is (A,B).

Question 17

Which of the following heat treatment processes is/are used for surface hardening of steels?

(A) Carburizing
(B) Cyaniding
(C) Annealing
(D) Carbonitriding

Ans. **(A, B, D)**

Sol. Heat treatment process is/are used for surface hardening of steel-

- Cyaniding
- Carbonitriding
- Carburizing

Note : Surface hardening process $\rightarrow$ Cyaniding, Carbonitriding, Carburizing.

Surface softening process $\rightarrow$ Annealing.

Hence, the correct option is (A,B,C).

Question 18

Which of the following additive manufacturing technique(s) can use a wire as a feedstock material?

(A) Stereolithography
(B) Fused deposition modeling
(C) Selective laser sintering
(D) Directed energy deposition processes

Ans. **(B & D)**

Sol. Wire is used as feed stock material in two manufacturing technique which are :

- Fused deposition modelling
- Directed energy deposition processes.

Hence, the correct option is (B,D).

Question 19

Which of the following methods can improve the fatigue strength of a circular mild steel (*MS*) shaft?

(A) Enhancing surface finish
(B) Shot peening of the shaft
(C) Increasing relative humidity
(D) Reducing relative humidity

Ans. **(A, B, D)**

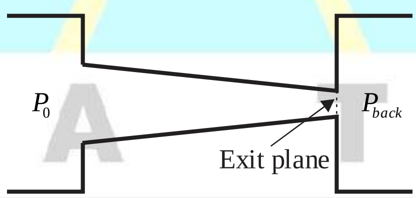
Sol. Method which can improve fatigue strength of a circular mild steel shaft are :

- Enhancing surface finish.
- Shot peening of the shaft.
- Reducing relative humidity

Hence, the correct option is (A,B,D).

Question 20

The figure shows a purely convergent nozzle with a steady, inviscid compressible flow of an ideal gas with constant thermophysical properties operating under choked condition. The exit plane shown in the figure is located within the nozzle. If the inlet pressure (P_0) is increased while keeping the back pressure (P_{back}) unchanged, which of the following statements is/are true?



(A) Mass flow rate through the nozzle will remain unchanged.
(B) Mach number at the exit plane of the nozzle will remain unchanged at unity.
(C) Mass flow rate through the nozzle will increase.
(D) Mach number at the exit plane of the nozzle will become more than unity.

Ans. **(B,C)**

Sol. In a purely convergent nozzle with a steady inviscid compressible flow of an ideal gas.

* Mass flow rate through the nozzle will increase.

$$(\dot{m})_{\max} = 0.685 \times A_2 \sqrt{P_1 \rho_1}$$

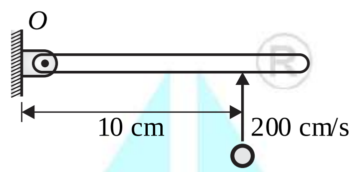
$$P_1(P_0)\uparrow = \dot{m}_{\max}\uparrow$$

* Mach number at the exit plane of the nozzle will remain unchanged at unity.

Hence, the correct option is (B,C).

Question 21

The plane of the figure represents a horizontal plane. A thin rigid rod at rest is pivoted without friction about a fixed vertical axis passing through O. Its mass moment of inertia is equal to 0.1 kg·cm^2 about O. A point mass of 0.001 kg hits it normally at 200 cm/s at the location shown, and sticks to it. Immediately after the impact, the angular velocity of the rod is ___________ rad/s (in integer).



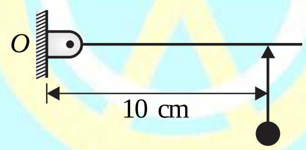
Ans. **10**

Sol. Given data

Mass of particle $(m) = 0.001$ kg

Velocity of particle $(v) = 200$ cm/s

Moment of inertia about point O $(I_0) = 0.1\ \text{kg} - \text{cm}^2$



Let us angular velocity of rod $= \omega_r'$ rad/s

We know, Momentum conservation principle

$$I_r\omega_r + I_m\omega_n = (I_r + I_m)\omega_r'$$

$$0 + 0.001\times10^2 \times \frac{200}{10} = (0.1 + 0.001\times10^2)\times\omega_r'$$

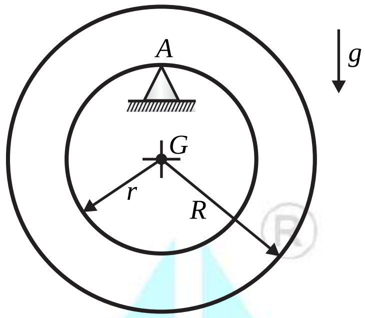
$$\omega_r' = 10 \text{ rad/s}$$

Hence, the angular velocity of rod $\omega_r' = 10$ rad/s

Hence, the correct answer is 10.

Question 22

A rigid uniform annular disc is pivoted on a knife edge A in a uniform gravitational field as shown, such that it can execute small amplitude simple harmonic motion in the plane of the figure without slip at the pivot point. The inner radius r and outer radius R are such that $r^2 = R^2/2$, and the acceleration due to gravity is g. If the time period of small amplitude simple harmonic motion is given by $T = \beta\pi\sqrt{R/g}$, where π is the ratio of circumference to diameter of a circle, then β = ________ (round off to 2 decimal places).



Ans. **2.659**

Sol. Given,

$$r^2 = \frac{R^2}{2}$$

Where,

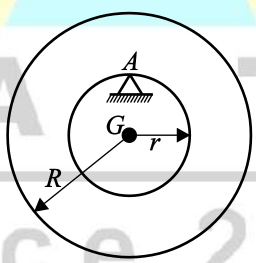
$r =$ Inner radius of disc

$R =$ Outer radius of disc

Motion of disc = Simple harmonic motion (SHM)

Acceleration $= g$

Time period of oscillation $(T) = \beta\pi\sqrt{\frac{R}{g}}$ … (i)



Mass moment of inertia about centre of gravity (I_G)

$$I_G = M\frac{(R^2 + r^2)}{2} = M\frac{\left(R^2 + \frac{R^2}{2}\right)}{2}$$

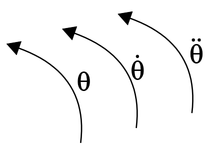
$$I_G = \frac{3}{4}MR^2$$

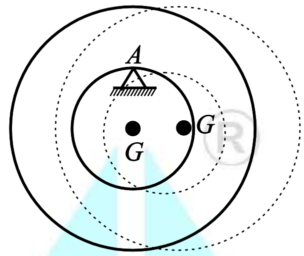
$$I_A = I_G + Mr^2$$

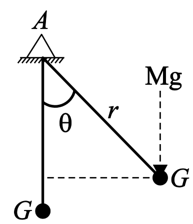
$$= \frac{3}{4}MR^2 + \frac{MR^2}{2}$$

$$I_A = \frac{5}{4}MR^2 \qquad \text{… (ii)}$$

Disc rotated θ angle







$$+ \quad \sum T_A = I_A \propto$$

Where,

$T_A \rightarrow$ Torque about A

$\alpha \rightarrow$ Angular acceleration

$$-Mg \times r\sin\theta = \frac{5}{4}MR^2\ddot{\theta}$$

$$\frac{5}{4}MgR^2\ddot{\theta} + Mg\frac{R}{\sqrt{2}} = 0$$

$$\frac{5\sqrt{2}R\ddot{\theta}}{M_e} + \frac{4g}{k_e} = 0$$

$$5\sqrt{2}R\ddot{\theta} + 4g\,\theta = 0 \qquad \text{…. (iii)}$$

We know,

$$m_e\,\ddot{\theta} + k_e\,\theta = 0 \qquad \text{…. (iV)}$$

We know,

$$\omega_n = \sqrt{\frac{k_e}{M_e}}$$

$$\omega_n = \sqrt{\frac{4g}{R \times 5\sqrt{2}}}$$

$$\omega_n = 0.752\sqrt{\frac{g}{R}}$$

Since, Time period $(T) = \dfrac{2\pi}{\omega_n}$ ... (v)

From equation (i) & (v)

$$\beta\pi\sqrt{\frac{R}{g}} = \frac{2\pi}{0.752}\sqrt{\frac{R}{g}}$$

$$\beta = 2.659 \text{ rad/s}$$

Hence, the correct answer is 2.659.

Question 23

Electrochemical machining operations are performed with tungsten as the tool, and copper and aluminum as two different workpiece materials. Properties of copper and aluminum are given in the table below.

Material	**Atomic mass (amu)**	**Valency**	**Density (g/cm³)**
Copper	63	2	9
Aluminum	27	3	2.7

Ignore overpotentials, and assume that current efficiency is 100% for both the workpiece materials. Under identical conditions, if the material removal rate (MRR) of copper is 100 mg/s, the MRR of aluminum will be ___________ mg/s (round-off to two decimal places).

Ans. **28.5**

Sol. **Given :**

Faraday's constant $(F) = 96500$

Current efficiency $= 100\%$

Material removal rate of Cu $(MRR_{Cu}) = 100$ mg/s

$$= 100 \times 10^{-3} \text{ g/s}$$

Material	**Atomic Mass (A)**	**Valency (z)**	**ρ(g/cm³)**
Cu	63	2	9
Al	27	3	2.7

Material removal rate,

$$MRR = \frac{AI}{ZF}$$

For Cu, $MRR_{Cu} = \left(\dfrac{AI}{ZF}\right)_{Cu}$

$$100\times10^{-3}=\frac{63\times I}{2\times96500}$$

$$I=306.34\text{ Amp}$$

For Al, $MRR_{AL}=\left(\frac{AI}{ZF}\right)_{AL}=\frac{27\times306.34}{3\times96500}$

$$MRR_{AL}==0.0285\text{ g/sec}=28.5\text{ mg/s}$$

Hence, the correct answer is 28.5

Question 24

A polytropic process is carried out from an initial pressure of 110 kPa and volume of 5 m^3 to a final volume of 2.5 m^3. The polytropic index is given by n = 1.2. The absolute value of the work done during the process is _______ kJ (round off to 2 decimal places).

Ans. **408.912**

Sol. **Given**

Initial pressure $P_1=110$ kPa

Initial volume $(V_1)=5\text{ m}^3$

Polytrophic index $(\eta)=1.2$

Final volume $(V_2)=2.5\text{ m}^3$

From polytropic process,

$$P_1V_1^{\eta}=P_2V_2^{\eta}$$

$$140\times5^3=P_2(2.5)^{\eta}$$

$$P_2=252.713\text{ kPa}$$

Work done $=\frac{P_1V_1-P_2V_2}{\eta-1}=\frac{110\times5-252.713\times2.5}{0.2}=408.912$ kJ (absolute value)

Hence, the correct answer is 408.912.

Question 25

A flat plate made of cast iron is exposed to a solar flux of 600 W/m^2 at an ambient temperature of 25^0C. Assume that the entire solar flux is absorbed by the plate.

Cast iron has a low temperature absorptivity of 0.21. Use Stefan-Boltzmann constant $=5.669\times10^{-8}\text{ W/m}^2\text{-K}^4$. Neglect all other modes of heat transfer except radiation.

Under the aforementioned conditions, the radiation equilibrium temperature of the plate is __________ ^{0}C (round off to the nearest integer).

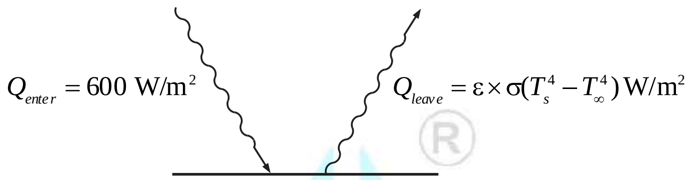
Ans. **218.33**

Sol. Solar flux $(Q_{enter}) = 600\,\text{W/m}^2$

Absorptivity $(\alpha) = 0.21$

Ambient temperature $(T_\infty) = 25^0\text{C} = 298\text{ K}$

Stefan Boltzmann constant $(\sigma) = 5.66\times10^{-8}\,\text{W/m}^2\,\text{K}^4$



Because all flux is absorbed by the plate, so, we can say that the value of absorptivity is equal to 1.

From Kirchoff's law,

Emissivity = absorptivity, $\varepsilon = \alpha = 0.21$

At equilibrium, $Q_{enter} = Q_{leave}$

$$600 = \sigma\varepsilon(T_s^4 - T_\infty^4)$$

$$600 = 0.21\times5.669\times10^{-8}(T_s^4 - 298^4)$$

$$T_s = 491.33\text{K}$$

$$T_s = 218.33^0\text{C}$$

Hence, the correct answer is 218.33.

Question 26

The value of the integral

$$\oint\left(\frac{6z}{2z^4 - 3z^3 + 7z^2 - 3z + 5}\right)dz$$

evaluated over a counter-clockwise circular contour in the complex plane enclosing only the pole $z = i$, where i is the imaginary unit, is

(A) $(-1+i)\pi$ (B) $(1+i)\pi$ (C) $2(1-i)\pi$ (D) $(2+i)\pi$

Ans. **(A)**

Sol. **Given :** Integral $I = \oint\left(\frac{6z}{2z^4 - 3z^3 + 7z^2 - 3z + 5}\right)dz$

The given integral is evaluated over a counter-clockwise circular contour in the complex plane enclosing only the pole $z = i$, where i is the imaginary unit.

We know that,

$$I = 2\pi i\times\text{Res}\,(z = a)$$

$$I = 2\pi i \times \text{Res}(z = i) \qquad \ldots\text{(i)}$$

Complex function,

$$f(z) = \frac{6z}{2z^4 - 3z^3 + 7z^2 - 3z + 5}$$

Residue at pole $z = i$,

$$\text{Res}(z = a) = \lim_{z \to a} f(z)(z - a)$$

$$\text{Res}(z = i) = \lim_{z \to i} \frac{6z}{2z^4 - 3z^3 + 7z^2 - 3z + 5}(z - i)$$

$$\text{Res}(z = i) = \lim_{z \to i} \frac{6z^2 - 6zi}{2z^4 - 3z^3 + 7z^2 - 3z + 5}$$

By putting the limit, it becomes $\left(\frac{0}{0}\right)$ form.

We can apply L' hospital rule,

$$\text{Res}(z = i) = \lim_{z \to i} \frac{12z - 6i}{8z^3 - 9z^2 + 14z - 3}$$

$$\text{Res}(z = i) = \frac{12i - 6i}{8 \times i^3 - 9 \times i^2 + 14i - 3} = \frac{6i}{-8i + 9 + 14i - 3}$$

$$\text{Res}(z = i) = \frac{6i}{6 + 6i} = \frac{i}{1 + i} = \frac{i}{1 + i} \times \frac{1 - i}{1 - i}$$

$$\text{Res}(z = i) = \frac{i(1 - i)}{1^2 - i^2} = \frac{i - i^2}{1 + 1} = \frac{i + 1}{2} = \frac{1 + i}{2}$$

From equation (i),

$$I = 2\pi i \times \text{Res}(z = i)$$

$$I = 2\pi i \times \frac{1 + i}{2}$$

$$I = \pi i(1 + i)$$

$$I = \pi(i + i^2)$$

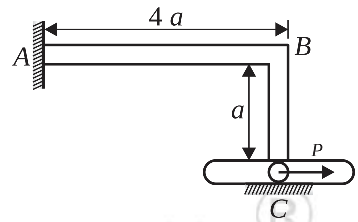
$$I = \pi(i - 1)$$

$$I = (-1 + i)\pi$$

Hence, the correct option is (A).

Question 27

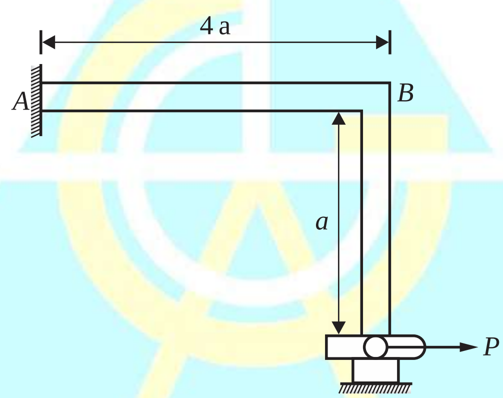
An L-shaped elastic member *ABC* with slender arms *AB* and *BC* of uniform cross-section is clamped at end *A* and connected to a pin at end *C*. The pin remains in continuous contact with and is constrained to move in a smooth horizontal slot. The section modulus of the member is same in both the arms. The end C is subjected to a horizontal force P and all the deflections are in the plane of the figure. Given the length AB is $4a$ and length BC is a, the magnitude and direction of the normal force on the pin from the slot, respectively, are



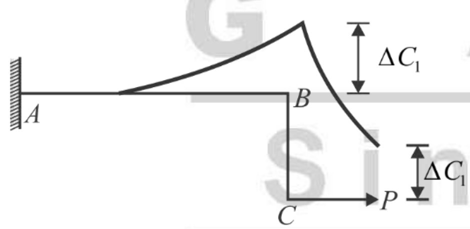
(A) $3P/8$, and downwards
(B) $5P/8$, and upwards
(C) $P/4$, and downwards
(D) $3P/4$, and upwards

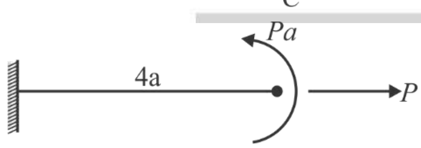
Ans. **(A)**

Sol.



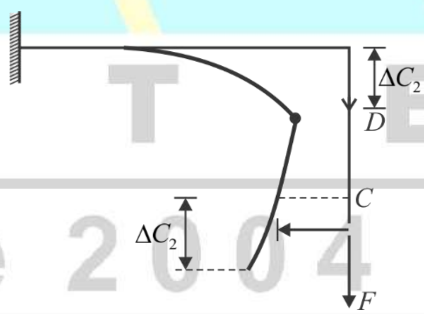
Deflection in x-direction due to load P

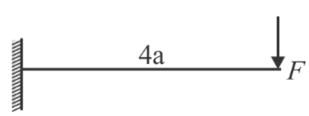




$$\Delta C_1 = \frac{Pa(4a)^2}{2EI}$$

Deflection in y-direction due to load P





$$\Delta C_2 = \frac{F(4a)^3}{3EI}$$

$$\Delta C_1 = \frac{8Pa^3}{EI} \quad \ldots \text{(i)} \qquad \Delta C_2 = \frac{64Fa^3}{3EI} \quad \ldots \text{(ii)}$$

From equation (i) and (ii)

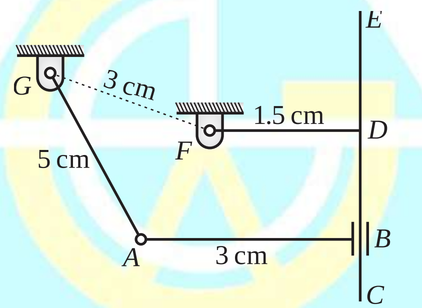
$$\frac{8Pa^3}{EI} = \frac{64a^3 \times F}{3EI}$$

$$F = \frac{3P}{8} \text{ downward.}$$

Hence, the correct option is (A).

Question 28

A planar four-bar linkage mechanism with 3 revolute kinematic pairs and 1 prismatic kinematic pair is shown in the figure, where $AB \perp CE$ and $FD \perp CE$. The T-shaped link *CDEF* is constructed such that the slider *B* can cross the point *D*, and *CE* is sufficiently long. For the given lengths as shown, the mechanism is



(A) a Grashof chain with links *AG*, *AB*, and *CDEF* completely rotatable about the ground link *FG*

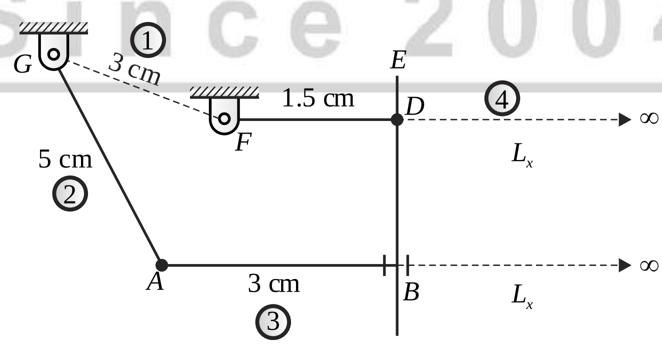
(B) a non-Grashof chain with all oscillating links

(C) a Grashof chain with *AB* completely rotatable about the ground link *FG*, and oscillatory links *AG* and *CDEF*

(D) on the border of Grashof and non-Grashof chains with uncertain configuration(*s*)

Ans. (A)

Sol.



Link (1) $= 3$ cm $\rightarrow$ shortest

Link (2) $=5$ cm

Link (3) $=3$ cm + $L_x \rightarrow$ Longest

Link (4) $=1.5\,\text{cm}+L_x$

$S+l \le p+q$

$3+3+L_x \le 5+1.5+L_x$

$6 \le 6.5$

Law satisfied and shortest link is fixed $\rightarrow$ Double crank

Hence, the correct option is (A).

Question 29

Consider a forced single degree-of-freedom system governed by $\ddot{x}(t)+2\zeta\omega_n\dot{x}(t)+\omega_n^2 x(t)=\omega_n^2\cos(\omega t)$, where ζ and ω_n are the damping ratio and undamped natural frequency of the system, respectively, while ω is the forcing frequency. The amplitude of the forced steady state response of this system is given by $\left[\left(1-r^2\right)^2+\left(2\zeta r\right)^2\right]^{-1/2}$, where $r=\omega/\omega_n$. The peak amplitude of this response occurs at a frequency $\omega=\omega_p$. If ω_d denotes the damped natural frequency of this system, which one of the following options is true?

(A) $\omega_p<\omega_d<\omega_n$

(B) $\omega_p=\omega_d<\omega_n$

(C) $\omega_d<\omega_n=\omega_p$

(D) $\omega_d<\omega_n<\omega_p$

Ans. **(A)**

Sol. Given

$$r=\frac{\omega}{\omega_n}$$

$$\frac{\omega}{\omega_n}=r=\sqrt{1-2\xi^2}$$

$$\omega_p=\omega_n\sqrt{1-2\xi^2} \quad \ldots \text{(i)}$$

$(\omega=\omega_p)$ when peak amplitude is occur.

So from equation (i) we can conclude $\omega_p<\omega_n$

And we know that,

Damped frequency, $\omega_d=\sqrt{1-\xi^2}\,\omega_n$

Value of $(\xi < 1)$ always

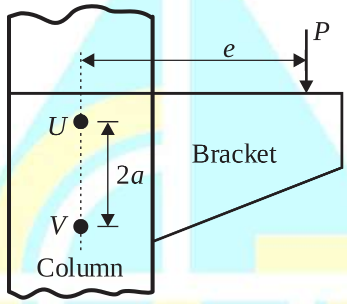
So, $\omega_d < \omega_n$

So, the sequence will be $\omega_p < \omega_d < \omega_n$

Hence the correct option is (A).

Question 30

A bracket is attached to a vertical column by means of two identical rivets *U* and *V* separated by a distance of $2a$ = 100 mm, as shown in the figure. The permissible shear stress of the rivet material is 50 MPa. If a load *P* = 10 kN is applied at an eccentricity $e = 3\sqrt{7}a$, the minimum cross-sectional area of each of the rivets to avoid failure is ___________ mm^2.



(A) 800 (B) 25 (C) $100\sqrt{7}$ (D) 200

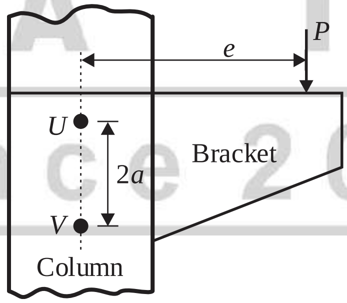
Ans. **(A)**

Sol. **Given :**

Load $P = 10$ kN

Distance $2a = 100$ mm

Eccentricity $(e) = 3\sqrt{7}a$



Primary force

$$P_p = \frac{10 \times 10^3}{2} = 5000 \text{ N}$$

$$P_{secondary} = P \times e = \frac{Ps_1}{2a} \times 4a^2$$

$$10\times10^{3}\times3\sqrt{7}a = Ps_{1}\times2a$$

$$Ps_{1} = 39686.26\text{ N}$$

$$R = \sqrt{P_{p}^{2}+P_{s}^{2}}$$

$$= \sqrt{5000^{2}+39686.26^{2}}$$

$$R_{\max} = 40000\text{ N}$$

$$\frac{R_{\max}}{A} = \tau$$

$$\frac{400000}{50} = A$$

$$A = 800\text{ mm}^{2}$$

Hence, the correct option is (A).

Question 31

In $Fe-Fe_{3}C$ phase diagram, the eutectoid composition is 0.8 weight % of carbon at 725^{0}C. The maximum solubility of carbon in $\alpha-$ferrite phase is 0.025 weight % of carbon. A steel sample, having no other alloying element except 0.5 weight % of carbon, is slowly cooled from 1000^{0}C to room temperature. The fraction of pro-eutectoid $\alpha-$ferrite in the above steel sample at room temperature is

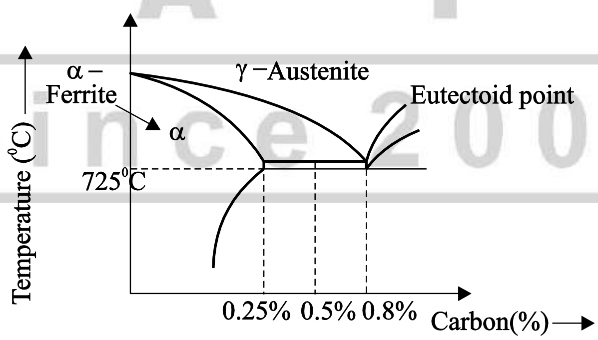
(A) 0.387 (B) 0.864 (C) 0.475 (D) 0.775

Ans. **(A)**

Sol. **Given data**

The eutectoid composition at $725^{0}C = 0.8\%$ carbon

$\alpha-$ Ferrite phase $= 0.025\%$ Carbon



$$\text{Fraction of pro – eutectoid } (m_{\alpha}) = \frac{0.8-0.5}{0.8-0.25}$$

$$m_{\alpha} = 0.387$$

Hence the correct option is (A).

Question 32

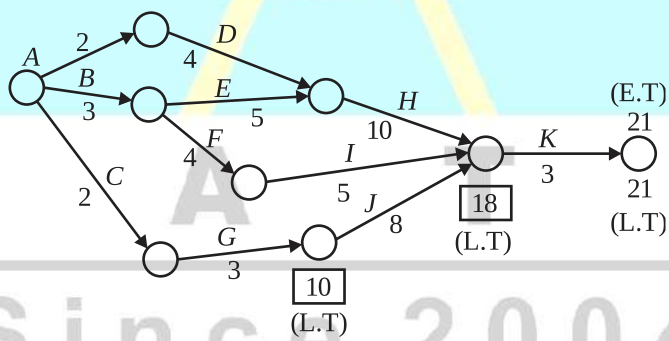
Activities *A* to *K* are required to complete a project. The time estimates and the immediate predecessors of these activities are given in the table. If the project is to be completed in the minimum possible time, the latest finish time for the activity *G* is ____________ hours.

Activity	Time (hours)	Immediate predecessors
A	2	-
B	3	-
C	2	-
D	4	A
E	5	B
F	4	B
G	3	C
H	10	D, E
I	5	F
J	8	G
K	3	H, I, J

(A) 5 (B) 10 (C) 8 (D) 9

Ans. **(B)**

Sol. Latest finish time for activity $G = 10$ hours



Hence, the correct option is (B).

Question 33

A solid spherical bead of lead (uniform density = 11000 kg/m^3) of diameter d = 0.1 mm sinks with a constant velocity V in a large stagnant pool of a liquid (dynamic viscosity$=1.1\times10^{-3}$ kg$\cdot$m$^{-1}\cdot$s^{-1}). The coefficient of drag is given by $c_D = \dfrac{24}{\text{Re}}$, where the Reynolds number (Re) is defined on the basis of the diameter of the bead. The drag force acting on the bead is expressed as $D = (c_D)(0.5\rho V^2)\left(\dfrac{\pi d^2}{4}\right)$, where

ρ is the density of the liquid. Neglect the buoyancy force. Using $g = 10 \text{ m/s}^2$, the velocity V is __________ m/s.

(A) $\frac{1}{24}$ (B) $\frac{1}{6}$ (C) $\frac{1}{18}$ (D) $\frac{1}{12}$

Ans. (C)

Sol. Given :

Density of spherical bead, $(\rho_{spherical\ bead}) = 11000 \text{ kg/m}^3$

Diameter, $(d) = 0.1$ mm

Dynamic viscosity, $(\mu) = 1.1 \times 10^{-3}$ kg/m-sec

Coefficient of drag, $(C_D) = \frac{24}{\text{Re}}$

Neglect Buoyancy force $(F_B = 0)$

$$F_D = C_D \times 0.5\,3V^2 \left(\frac{\pi d^2}{4}\right)$$

$$F_D + F_B = \text{Weigth of spherical bead}$$

$$C_D \times 0.5 \times \rho_{water} \times V^2 \times \frac{\pi d^2}{4} = \frac{4\pi}{3}\left(\frac{d}{2}\right)^3 \times \rho_{spherical\ bead}\, g$$

$$\frac{24\mu}{\rho_{water} V d} \times 0.5 \times \rho_{water} \times V^2 \times \frac{\pi d^2}{4} = \frac{4}{3}\pi\left(\frac{d}{2}\right) \times \rho_{spherical\ bead} \times g$$

$$\frac{24 \times 1.1 \times 10^{-3}}{0.1 \times 10^{-3}} \times 0.5 \times \frac{\pi}{4} \times (0.1 \times 10^{-3})^2 \times V = \frac{4}{3} \times \pi \times \left(\frac{0.1 \times 10^{-3}}{2}\right)^3 \times 11000 \times 10$$

$$264 \times 0.5 \times V \times 7.85 \times 10^{-9} = 5.75 \times 10^{-8}$$

$$V = \frac{1}{18} \text{ m/sec} = 0.055 \text{ m/sec}$$

Hence, the correct option is (C).

Question 34

Consider steady, one-dimensional compressible flow of a gas in a pipe of diameter 1 m. At one location in the pipe, the density and velocity are 1 kg/m^3 and 100 m/s, respectively. At a downstream location in the pipe, the velocity is 170 m/s. If the pressure drop between these two locations is 10 kPa, the force exerted by the gas on the pipe between these two locations is ____________ N.

(A) $350\pi^2$ (B) 750π (C) 1000π (D) 3000

Ans. (B)

Sol. Given;

Diameter $(d) = 1$ m

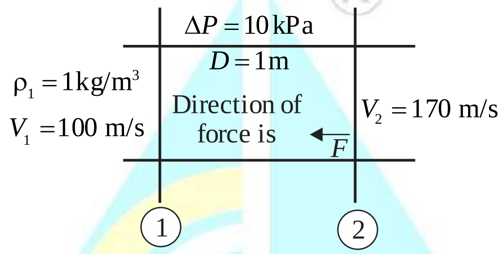
Density $(\rho) = 1 \text{kg/m}^3$

Velocity $(V_1) = 100$ m/s

Velocity $(V_2) = 170$ m/s

Pressure drop between two location =10 kPa

Force exerted by the gas on the pipe between two locations is



$$(P_1 - P_2) - F = m(V_2 - V_1)$$

$$(10\times10^3)\times\frac{\pi}{4}\times1^2 - F = \rho_1 A_1 V_1 [V_2 - V_1]$$

$$10\times10^3\times\frac{\pi}{4} - F = 1\times\frac{\pi}{4}\times d^2\times100[170-100]$$

$$F = 750\pi$$

Hence, the correct option is (B).

Question 35

Consider a rod of uniform thermal conductivity whose one end (x = 0) is insulated and the other end (x = L) is exposed to flow of air at temperature T_∞ with convective heat transfer coefficient h. The cylindrical surface of the rod is insulated so that the heat transfer is strictly along the axis of the rod. The rate of internal heat generation per unit volume inside the rod is given as

$$\dot{q} = \cos\frac{2\pi x}{L}.$$

The steady state temperature at the mid-location of the rod is given as T_A. What will be the temperature at the same location, if the convective heat transfer coefficient increases to 2h?

(A) $T_A + \frac{\dot{q}L}{2h}$

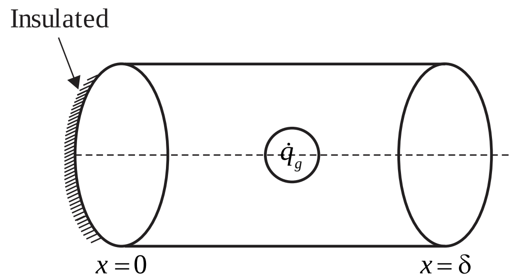
(B) $2T_A$

(C) T_A

(D) $T_A\left(1-\frac{\dot{q}L}{4\pi h}\right)+\frac{\dot{q}L}{4\pi h}T_\infty$

Ans. **(C)**

Sol.



General heat conduction equation for plane wall

$$\nabla^2 T + \frac{q_g}{k} = \frac{1}{\alpha}\frac{dT}{d\tau}$$

For one dimensional heat conduction with steady state

$$\frac{d^2T}{dx^2} + \frac{\dot{q}_g}{k} = 0$$

$$\frac{d^2T}{dx^2} = \frac{-\dot{q}_g}{k}$$

Integrate with respect to x

$$\frac{dT}{dx} = \frac{-q_g}{k}x + C_1 \qquad \ldots (A)$$

Again integrate

$$T = \frac{-q_g}{2k}x^2 + C_1 x + C_2 \qquad \ldots (B)$$

C_1 and C_2 are the integration constant

Boundary conditions

At $x = 0, \dot{Q} = 0$

At $x = \delta, T = T_w$

Apply first boundary equation

(1) At $x = 0, \dot{Q}_{cond} = 0$

$$-kA\frac{dT}{dx} = 0$$

$$\frac{dT}{dx} = 0$$

At, $x = 0, \left.\frac{dT}{dx}\right|_{x=0} = 0$

From, equation (A)

$$C_1 = 0$$

(2) Second boundary condition

At $x = \delta,\ T = T_w$ Put in equation (B)

$$T_w = \frac{-q_g}{2k}\delta^2 + C_2$$

$$C_2 = T_w + \frac{\dot{q}_g}{2k}\delta^2$$

Put the value of C_1 and C_2 in equation (B),

$$T = T_w + \frac{\dot{q}_g}{2k}(\delta^2 - x^2) \quad \text{(Temperature variation (}2^0\text{ parabola))}$$

According to question

$$T_A = T_w + \frac{\cos\frac{2\pi x}{L}}{2k}(\delta^2 - x^2)$$

(Because $\dot{q}_g = \cos\frac{2\pi x}{L}$, when $h_1 = H$)

At $\delta = \frac{x}{2}$ (at mid plane)

$$T = T_w + \frac{\cos\frac{2\pi x}{L}}{2k}\left(\frac{x^2}{4} - x^2\right) \quad \text{... (C)}$$

Equation (iii) shows the temperature distribution equation which is independent of heat transfer coefficient.

So there is no effect of heat transfer coefficient on temperature T_A.

Hence, the correct option is (C).

Question 36

The system of linear equations in real (x, y) given by $(x\ y)\begin{bmatrix} 2 & 5-2\alpha \\ \alpha & 1 \end{bmatrix} = (0\ 0)$ involves a real parameter α and has infinitely many non-trivial solutions for special value(s) of α. Which one or more among the following options is/are non-trivial solution(s) of (x, y) for such special value(s) of α?

(A) $x = 2,\ y = -2$

(B) $x = -1,\ y = 4$

(C) $x = 1,\ y = 1$

(D) $x = 4,\ y = -2$

Ans. **(A, B)**

Sol. **Given :** The system of linear equations in real (x, y),

$$\begin{bmatrix} x & y \end{bmatrix}\begin{bmatrix} 2 & 5-2\alpha \\ \alpha & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 \end{bmatrix} \qquad \ldots\text{(i)}$$

As we know that,

System of linear equation,

$$AX = 0 \qquad \ldots\text{(ii)}$$

By equation (i) and (ii), we get

$$\text{Matrix } [A] = \begin{bmatrix} 2 & 5-2\alpha \\ \alpha & 1 \end{bmatrix}$$

It has infinity many non-trivial solutions for special values of α.

That means det (A) will be zero.

$$\det(A) = \begin{vmatrix} 2 & 5-2\alpha \\ \alpha & 1 \end{vmatrix} = 0$$

$$2 \times 1 - (5-2\alpha) \times \alpha = 0$$

$$2 - 5\alpha + 2\alpha^2 = 0$$

$$2\alpha^2 - 5\alpha + 2 = 0$$

$$\alpha = 2, \frac{1}{2}$$

For $\alpha = 2$,
$$[A] = \begin{bmatrix} 2 & 5-2\alpha \\ \alpha & 1 \end{bmatrix} = \begin{bmatrix} 2 & 1 \\ 2 & 1 \end{bmatrix}$$

System of linear equation will be,

$$\begin{bmatrix} x & y \end{bmatrix}_{1\times 2}\begin{bmatrix} 2 & 1 \\ 2 & 1 \end{bmatrix}_{2\times 2} = \begin{bmatrix} 0 & 0 \end{bmatrix}_{1\times 2}$$

$$2x + 2y = 0 \text{ and } x + y = 0$$

$$x = -y \qquad \ldots\text{(iii)}$$

For $\alpha = \frac{1}{2}$,
$$[A] = \begin{bmatrix} 2 & 5-2\times(1/2) \\ 1/2 & 1 \end{bmatrix} = \begin{bmatrix} 2 & 4 \\ 1/2 & 1 \end{bmatrix}$$

System of linear equation will be,

$$\begin{bmatrix} x & y \end{bmatrix}_{1\times 2}\begin{bmatrix} 2 & 4 \\ 1/2 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 \end{bmatrix}$$

$$2x+\frac{y}{2}=0 \text{ and } 4x+y=0$$

$$2x=-\frac{y}{2}$$

$$4x=-y \qquad \ldots\text{(iv)}$$

For equation (iii) and (iv), only $x=-1,\ y=4$ and $x=2,\ y=-2$ are satisfied.

Hence, the correct option are (A,B).

Question 37

Let a random variable X follow Poisson distribution such that $\text{Prob}(X=1)=\text{Prob}(X=2)$. The value of $\text{Prob}(X=3)$ is __________ (round off to 2 decimal places).

Ans. **0.18**

Sol. **Given :** Random variable x follows poisson's distribution

$$\text{prob}\,(x=1)=\text{prob}\,(x=2)$$

Poisson's distribution,

$$p(r)=\frac{e^{-m}\,m^{r}}{r\,!} \qquad \text{where } m\rightarrow \text{mean}$$

$$\frac{e^{-m}\,m^{1}}{1!}=\frac{e^{-m}\,m^{2}}{2!}$$

$$m=\frac{m^{2}}{2}$$

$m=2$, mean of Poisson's distribution,

$$p(x=3)=\frac{e^{-2}\,2^{3}}{3!}=\frac{8e^{-2}}{6}=0.18$$

Hence, the correct answer is 0.18.

Question 38

Consider two vectors:

$$\vec{a}=5i+7j+2k$$

$$\vec{b}=3i-j+6k$$

Magnitude of the component of $\vec{a}$ orthogonal to $\vec{b}$ in the plane containing the vectors $\vec{a}$ and $\vec{b}$ is __________ (round off to 2 decimal places).

Ans. **8.32**

Sol. **Given :** Two vectors,

$$\vec{a} = 5\hat{i} + 7\hat{j} + 2\hat{k}$$
$$\vec{b} = 3\hat{i} - \hat{j} + 6\hat{k}$$

Magnitude of $\vec{a}$ orthogonal to $\vec{b}$ in plane of $\vec{a}$ and $\vec{b} = \left\| a \right| \sin\theta \right|$

$$\cos\theta = \frac{\vec{a}\cdot\vec{b}}{|\vec{a}|\cdot|\vec{b}|}$$

$$= \frac{5\times3 - 7\times1 + 2\times6}{\sqrt{5^2+7^2+2^2}\cdot\sqrt{3^2+(-1)^2+6^2}} = \frac{20}{\sqrt{78}\cdot\sqrt{46}}$$

$$\theta = 70.495^0$$

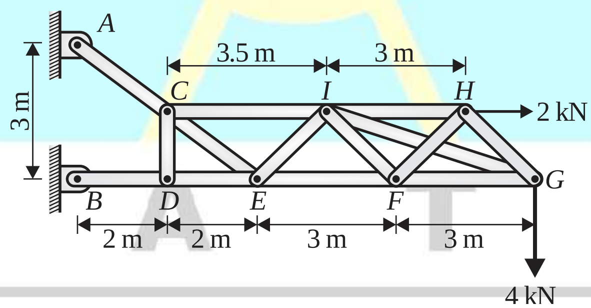
We know that,

$$\left\| a \right| \sin\theta \right| = \left|\sqrt{78}\sin(70.495^0)\right|$$
$$= 8.32$$

Hence, the correct answer is 8.32.

Question 39

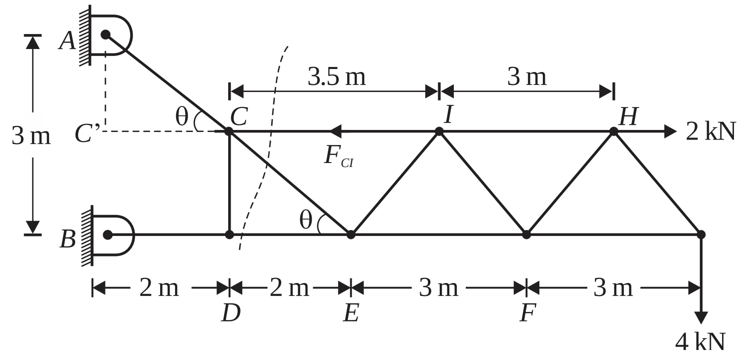
A structure, along with the loads applied on it, is shown in the figure. Self-weight of all the members is negligible and all the pin joints are friction-less. *AE* is a single member that contains pin *C*. Likewise, *BE* is a single member that contains pin *D*. Members *GI* and *FH* are overlapping rigid members. The magnitude of the force carried by member *CI* is ________ kN (in integer).



Ans. **18**

Sol.

FBD



Because AE is a single link

In $\Delta(AEB)$ $\tan\theta = \frac{3}{4}$

$$\theta = 36.86$$

In triangle ACC'

$$\tan\theta = \frac{AC'}{CC'} = \frac{AC'}{2}$$

$$\tan(36.86)\times 2 = AC'$$

$$AC' = 1.5 \text{ m}$$

$$C'B = AB - AC'$$

$$= 3 - 1.5 = 1.5 \text{ m}$$

Apply method of section, take moment at point (E)

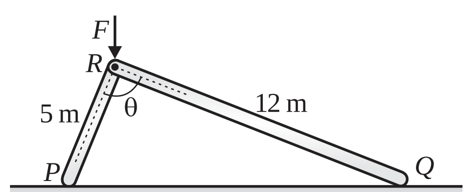
$$F_{CI}\times 1.5 = 2\times 1.5 + 4\times 6$$

$$F_{CI} = 18 \text{ kN}$$

Hence, the correct answer is 18.

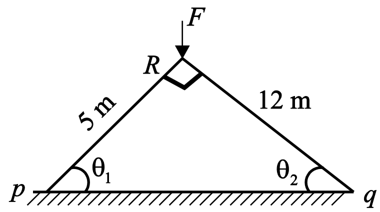
Question 40

Two rigid massless rods PR and RQ are joined at frictionless pin-joint R and are resting on ground at P and Q, respectively, as shown in the figure. A vertical force F acts on the pin R as shown. When the included angle $\theta < 90^0$, the rods remain in static equilibrium due to Coulomb friction between the rods and ground at locations P and Q. At $\theta = 90^0$, impending slip occurs simultaneously at points P and Q. Then the ratio of the coefficient of friction at Q to that at P (μ_Q/μ_P) is _________ (round off to two decimal places).

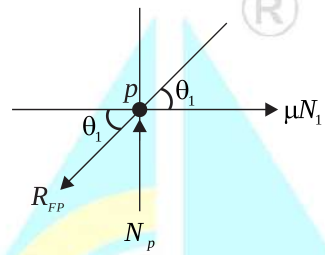


Ans. 5.8

Sol.



F_{BD} of point P



Calculation of angle

$$\tan\theta_1 = \frac{12}{5}$$

$$\theta_1 = 67.38^0$$

$$\tan\theta_2 = \frac{5}{12}$$

$$\theta_2 = 22.16^0$$

Apply $\Sigma x = 0$

$$\mu_p N_p = R_{FP}\cos 67.38 \quad \ldots (i)$$

Apply $\Sigma y = 0$

$$N_p = R_{FP} \times \sin 67.38 \quad \ldots (ii)$$

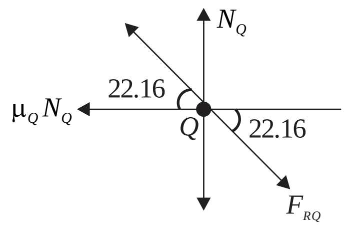
From equation (i) and equation (ii)

$$\mu_p \times R_{Fp}\sin 67.38 = F_{RP} \times \cos 67.38$$

$$\mu_p = \frac{\cos 67.38}{\sin 67.38}$$

$$\mu_p = 0.4166$$

F_{BD} of point Q



Apply $\Sigma x = 0$

$$\mu_Q N_Q = F_{RQ} \cos(22.16) \qquad \text{... (iii)}$$

Apply $\Sigma y = 0$

$$N_Q = F_{RQ} \sin(22.16) \qquad \text{... (iv)}$$

From (iii) and (iv)

$$\mu_Q F_{RQ} \sin(22.16) = F_{RQ} \cos(22.16)$$

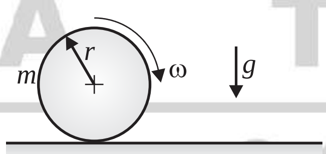
$$\mu_Q = 2.45$$

Ratio of $\dfrac{\mu_Q}{\mu_p} = \dfrac{2.45}{0.41} = 5.8$

Hence, the correct answer is 5.8.

Question 41

A cylindrical disc of mass m = 1 kg and radius r = 0.15 m was spinning at $\omega = 5$ rad/s when it was placed on a flat horizontal surface and released (refer to the figure). Gravity g acts vertically downwards as shown in the figure. The coefficient of friction between the disc and the surface is finite and positive. Disregarding any other dissipation except that due to friction between the disc and the surface, the horizontal velocity of the center of the disc, when it starts rolling without slipping, will be _________ m/s (round off to 2 decimal places).



Ans. **0.25**

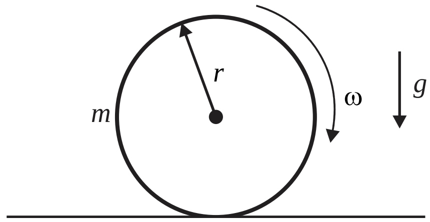
Sol. Given data :

Mass of cylindrical disc $(m) = 1$ kg

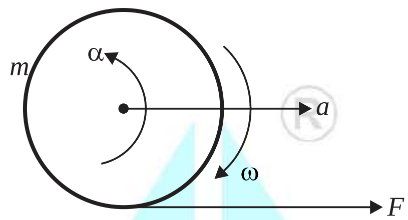
Radius of disc $(r) = 0.15$ m

Initial angular velocity of disc $(\omega_0) = 5$ rad/s

Gravitational acceleration $= g$ (m/s^2)



Let us horizontal velocity of disc $= v$ m/s



We know,

Newton's second law for linear motion

$$F = ma \quad \ldots \text{(i)}$$

And Newton's second law for angular motion

$$T = I_0 \times \alpha$$

$$T = \frac{mr^2}{2} \times \alpha \quad \ldots \text{(ii)}$$

Newton's 1st law of motion, for linear motion

$v = u + at$ [$u = 0$, because when disc touches the ground initial velocity will be zero]

$$v = \frac{F}{m} \times t$$

Newton's 1st law of motion for angular motion

$$\omega = \omega_0 - \alpha t$$

$$\frac{v}{r} = 5 - \frac{2F}{mr} \times \frac{vm}{F} \quad \text{(From equation (ii))}$$

$$\frac{v}{r} = 5 - \frac{2v}{r}$$

$$\frac{3v}{r} = 5$$

$$v = \frac{5 \times 0.15}{3}$$

$$v = 0.25 \text{ m/s}$$

Hence, the correct answer is 0.25.

Question 42

A thin-walled cylindrical pressure vessel has mean wall thickness of t and nominal radius of r. The Poisson's ratio of the wall material is 1/3. When it was subjected to some internal pressure, its nominal perimeter in the cylindrical portion increased by 0.1% and the corresponding wall thickness became $\bar{t}$. The corresponding change in the wall thickness of the cylindrical portion, i.e. $100\times(\bar{t}-t)/t$, is ________% (round off to 3 decimal places).

Ans. **– 0.06%**

Sol. **Given data**

Poisson's ratio $(\mu)=\dfrac{1}{3}$

Hoop strain $(\varepsilon_H)=0.1\%$

Hoop strain $(\varepsilon_H)=\dfrac{\delta D}{D}=\dfrac{1}{E}(\sigma_H-\mu\sigma_L)=\dfrac{0.1}{100}$

We know,

$$\sigma_H=\frac{PD}{2t},\sigma_L=\frac{\sigma_H}{2}=\frac{PD}{4t}$$

Therefore,

$$\varepsilon_H=\frac{1}{E}\left[\frac{PD}{2t}-\mu\frac{PD}{4t}\right]$$

$$\frac{0.1}{100}=\frac{PD}{4tE}(2-\mu) \qquad \ldots \text{(i)}$$

$$\varepsilon_R=\frac{\delta t}{t}=\frac{1}{E}\left(\sigma_R-\mu(\sigma_H+\sigma_L)\right)$$

$\because$ $$\sigma_R=0$$

$$\varepsilon_R=\frac{\delta t}{t}=\frac{1}{E}\left(0-\mu\left(\frac{PD}{2t}+\frac{PD}{4t}\right)\right)$$

$$=-\frac{\mu PD}{2tE}\left(\frac{3}{2}\right)$$

$$\frac{\delta t}{t}=-3\mu\frac{PD}{4tE} \qquad \ldots \text{(ii)}$$

From equation (i)

$$\frac{PD}{4tE}=\frac{0.001}{2-\mu}=\frac{0.001}{2-\frac{1}{3}} \qquad \ldots \text{(iii)}$$

From equation (ii) and (iii)

$$\frac{\delta t}{t} = -3 \times \frac{1}{3} \times \left(\frac{0.001 \times 3}{6-1}\right)$$

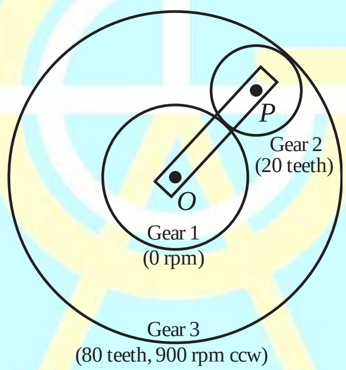
$$\frac{\delta t}{t} = -0.0006$$

$$\Rightarrow \qquad \frac{(\bar{t} - t)}{t} = \frac{\delta t}{t} = -0.06\%$$

Hence, the correct answer is – 0.06.

Question 43

A schematic of an epicyclic gear train is shown in the figure. The sun (gear 1) and planet (gear 2) are external, and the ring gear (gear 3) is internal. Gear 1, gear 3 and arm *OP* are pivoted to the ground at *O*. Gear 2 is carried on the arm *OP* via the pivot joint at *P*, and is in mesh with the other two gears. Gear 2 has 20 teeth and gear 3 has 80 teeth. If gear 1 is kept fixed at 0 rpm and gear 3 rotates at 900 rpm counter clockwise (ccw), the magnitude of angular velocity of arm *OP* is __________rpm (in integer).



Ans. **600**

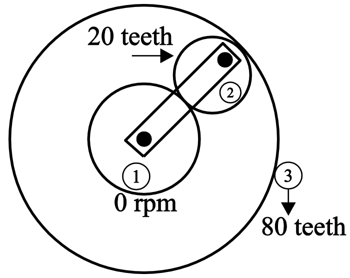
Sol. Given,

Teeth on gear 2 $(T_2) = 20$ teeth

Teeth on gear 3 $(T_3) = 80$

$N_1 = 0$ (Fixed gear)

$N_3 = -900$ rpm [CCW]



From above diagram

$$R_1 + 2R_2 = R_3$$

$$T_A + 2T_B = T$$

$$T_1 + 2T_2 = T_3 \qquad \text{[Because module is same]}$$

$$T_1 = 80 - 40$$

$$T_1 = 40 \text{ teeth}$$

From the concept of gear ratio

$$\frac{N_1 - N_{arm}}{N_3 - N_{arm}} = -\frac{T_2}{T_1} \times \frac{T_3}{T_2}$$

$$\frac{0 - N_{arm}}{-900 - N_{arm}} = -\frac{20}{40} \times \frac{80}{20}$$

$$\frac{-N_{arm}}{-900 - N_{arm}} = -2$$

$$N_{arm} = -600[CCW]$$

Magnitude $N_{arm} = 600$ rpm

Hence, the correct answer is 600.

Question 44

Under orthogonal cutting condition, a turning operation is carried out on a metallic workpiece at a cutting speed of 4 m/s. The orthogonal rake angle of the cutting tool is 5^0. The uncut chip thickness and width of cut are 0.2 mm and 3 mm, respectively. In this turning operation, the resulting friction angle and shear angle are 45^0 and 25^0, respectively. If the dynamic yield shear strength of the workpiece material under this cutting condition is 1000 MPa, then the cutting force is _______________ N (round off to one decimal place).

Ans. **2573.40**

Sol. Given: -

Rake angle $(\alpha) = 5^0$

Uncut chip thickness $(t_1) = 0.2$ mm

Friction angle $(\lambda) = 45^0$

Shear angle $(\phi) = 25^0$

Shear stress $(\tau) = 1000$ MPa

Width $(b) = 3$ mm

Shear force

$$F_S = \tau \times b \times \frac{t_1}{\sin\phi}$$

$$= 1000 \times 3 \times \frac{0.2}{\sin 25^0}$$

$$F_S = 1419.72$$

From merchant circle

$$\cos(\phi + \lambda - \alpha) = \frac{F_S}{R}$$

$$R = \frac{1419.72}{\cos(25 + 45 - 5)}$$

$$R = 3359.34 \text{ N}$$

$$\cos(\lambda - \alpha) = \frac{F_{cutting}}{R}$$

$$F_{cutting} = \cos(45 - 5) \times 3359.34$$

$$F_{cutting} = 2573.40 \text{ N}$$

Hence, the correct answer is 2573.40

Question 45

A 1 mm thick cylindrical tube, 100 mm in diameter, is orthogonally turned such that the entire wall thickness of the tube is cut in a single pass. The axial feed of the tool is 1 m/minute and the specific cutting energy (u) of the tube material is 6 J/mm^3. Neglect contribution of feed force towards power. The power required to carry out this operation is ________ kW (round off to one decimal place).

Ans. **31.4159**

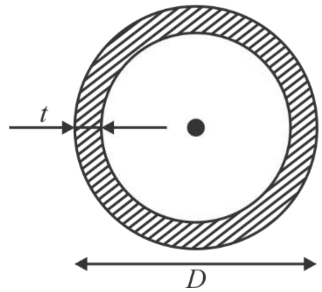
Sol. **Given :**

Thickness $(t) = 1$ mm

Diameter $(D) = 100$ mm

Axial feed $(F) = fN = 1 \text{ m/min} = \frac{1000}{60}$ mm/sec

Specific cutting energy $(G) = 6 \text{ J/mm}^3$



For cylindrical tube,

Area of cut $(A) = \pi D t$

Now,

$$\text{Specific cutting energy} = \frac{\text{Power}}{\text{Material removal rate}}$$

$$6 = \frac{P}{A \times fN}$$

$$6 = \frac{P}{\pi D t \times \left(\frac{1000}{60}\right)}$$

$$6 = \frac{P}{\pi \times 100 \times 1 \times \frac{1000}{60}}$$

Power required, $P = 31415.9$ W

$P = 31.4159$ kW

Hence, the correct answer is 31.4159

Question 46

A 4 mm thick aluminum sheet of width w = 100 mm is rolled in a two-roll mill of roll diameter 200 mm each. The workpiece is lubricated with a mineral oil, which gives a coefficient of friction, $\mu = 0.1$. The flow stress (σ) of the material in MPa is $\sigma = 207 + 414\varepsilon$, where ε is the true strain. Assuming rolling to be a plane strain deformation process, the roll separation force (F) for maximum permissible draft (thickness reduction) is __________ kN (round off to the nearest integer).

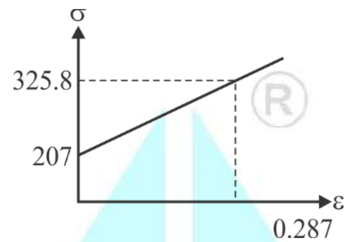
Use:

$F = 1.15\bar{\sigma}\left(1 + \frac{\mu L}{2\bar{h}}\right) wL$, where $\bar{\sigma}$ is average flow stress, L is roll- workpiece contact length, and $\bar{h}$ is the average sheet thickness.

Ans. **350.32**

Sol. Rolling, $h_0 = 4$ mm

$$W = 100\text{ mm}$$
$$D = 200\text{ mm}$$
$$\sigma = 207 + 414\varepsilon$$
$$(\Delta h)_{max} = 0.1^2 \times 100 = h_0 - h_f$$
$$h_f = 3\text{ mm}$$



$$\ln\left(\frac{4}{3}\right) = 0.287$$
$$\sigma = 207 + 414\varepsilon$$
$$\sigma = 325.818$$
$$\bar{\sigma} = \frac{207 + 325.818}{2} = 266.409\text{ MPa}$$
$$P = 1.15\bar{\sigma}\left(1 + \frac{uL}{2\bar{h}}\right) \qquad \text{we know that } \left[L = \sqrt{R\Delta h}\right]$$
$$P = 1.15 \times 266.409 \times \left(1 + \frac{0.4 \times 10}{2 \times 3.5}\right)$$
$$L = \sqrt{100 \times 1} = 10\text{ mm}$$
$$F = 1.15 \times 266.409 \times \left(1 + \frac{0.4 \times 10}{2 \times 3.5}\right) \times 100 \times 10 \qquad \bar{h} = \frac{4+3}{2} = 3.5\text{ mm}$$
$$F = 350.32\text{ kN}$$

Hence, the correct answer is 35.32.

Question 47

Two mild steel plates of similar thickness, in butt-joint configuration, are welded by gas tungsten arc welding process using the following welding parameters.

Welding voltage	20 V
Welding current	150 A
Welding speed	5 mm/s

A filler wire of the same mild steel material having 3 mm diameter is used in this welding process. The filler wire feed rate is selected such that the final weld bead is composed of 60% volume of filler and 40%

volume of plate material. The heat required to melt the mild steel material is 10 J/mm^3. The heat transfer factor is 0.7 and melting factor is 0.6. The feed rate of the filler wire is __________ mm/s (round off to one decimal place).

Ans. **10.695**

Sol. **Given :**

Voltage $(V) = 20$ V

Current $(I) = 150$ A

Welding speed $(V_s) = 5$ mm/s

Diameter of filler wire $(d) = 3$ mm

Heat required to meet m.s material $(Q) = 10$ J/mm^3

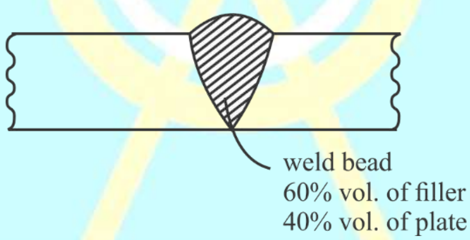
Heat transfer efficiency, $(\eta_{HT}) = 0.7$

Heat melting efficiency $(\eta_m) = 0.6$

Let feed rate of filler wire be f,

Input energy $(P_{in}) = VI$

$$= 150 \times 20 = 3000 \text{ J/sec}$$



Available energy $= \eta_{H.T} \times \eta_m \times P_{in}$

$$= 0.7 \times 0.6 \times 3000$$

$$= 1260 \text{ J/sec}$$

Rate of deposition of filler material = Cross-sectional Area of filler × feed rate

$$= \frac{\pi}{4} \times d^2 \times f$$

Rate of welding at which bead is forming

= Rate of deposition of filler material

∴ Area of weld × Welding speed × % Volume of filler

= Rate of deposition of filler material

∴ $$A_\omega \times V_S \times 0.6 = \frac{\pi}{4} \times d^2 \times f \qquad \ldots \text{(i)}$$

Heat required $(Q) = \dfrac{\text{Available energy}}{\text{Area of weld} \times \text{Welding speed}}$

$$10 = \frac{1260}{A_\omega \times 5}$$

$$A_\omega = 25.2 \text{ mm}^2$$

Putting value of A_ω in equation (i), we get

$$25.2 \times 5 \times 0.6 = \frac{\pi}{4} \times 3^2 \times f$$

Feed rate of wire, $(f) = 10.695$ mm/sec

Hence, the correct answer is 10.695.

Question 48

An assignment problem is solved to minimize the total processing time of four jobs (1, 2, 3 and 4) on four different machines such that each job is processed exactly by one machine and each machine processes exactly one job. The minimum total processing time is found to be 500 minutes. Due to a change in design, the processing time of Job 4 on each machine has increased by 20 minutes. The revised minimum total processing time will be _____________ minutes (in integer).

Ans. **520**

Sol. Given data

No. of Machine $(M) = M_1, M_2, M_3, M_4$

No. of job $(J) = J_1, J_2, J_3, J_4$

Total minimum processing time $= 500$ min

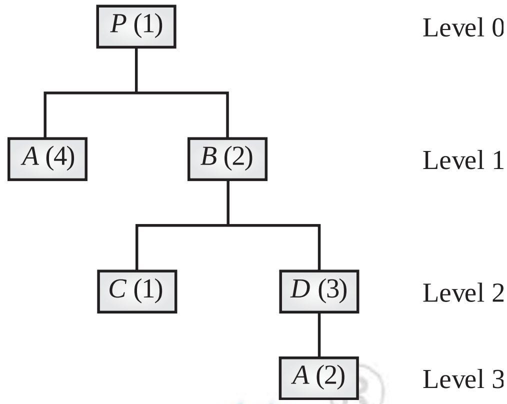
Processing time increased for each job $= 20$ min

Hence the revised total minimum processing time $= 520$ min

Hence, the correct answer is 520.

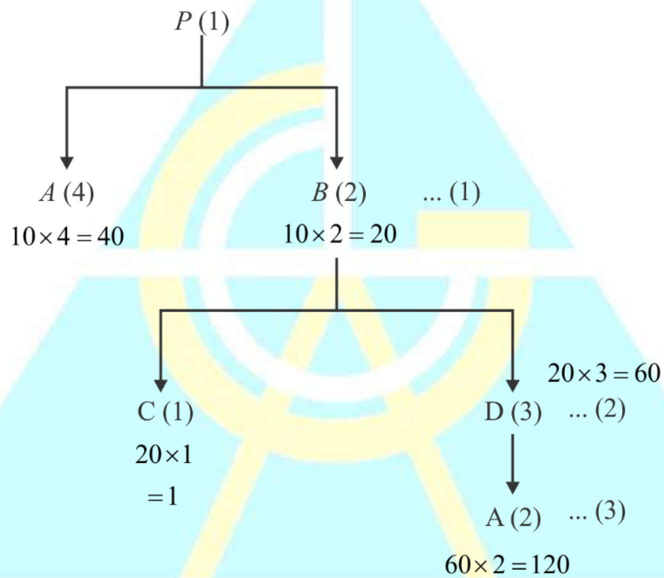
Question 49

The product structure diagram shows the number of different components required at each level to produce one unit of the final product P. If there are 50 units of on-hand inventory of component A, the number of additional units of component A needed to produce 10 units of product P is _________ (in integer).



Ans. **110**

Sol. Finds unit of A required for production of 10 unit of P



Total Required number A

$= 120 + 40$

$= 160 - 50$ In hand inventory (Instock)

$= 110$ unit of A required

Hence, the correct answer is 110.

Question 50

Consider a one-dimensional steady heat conduction process through a solid slab of thickness 0.1 m. The higher temperature side A has a surface temperature of 80^0C, and the heat transfer rate per unit area to low temperature side B is 4.5 kW/m^2. The thermal conductivity of the slab is 15 W/m.K. The rate of entropy generation per unit area during the heat transfer process is ________ W/m^2.K (round off to 2 decimal places).

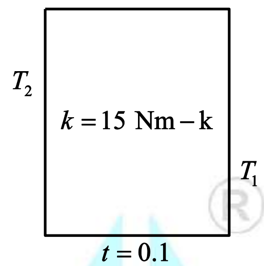
Ans. **1.1821**

Sol. Thickness $(t) = 0.1$ m

Temperature $(T_2) = 80^0\text{C} = 353$ k

Heat transfer rate per unit area $(Q) = 4.5\ \text{kW/m}^2$

Thermal conductivity $(k) = 15$ W/mk



$$q = \frac{\Delta T}{R_{th}}$$

$\because$ $$R_{th} = \frac{L}{k}.\text{A}$$

$$4.5\times10^3 = \frac{(80 - T_1)15}{0.1}$$

$\Rightarrow$ $$\frac{4.5\times10^3\times0.1}{15} = 80 - T_1$$

$\Rightarrow$ $$30 = 80 - T_1$$

$\Rightarrow$ $$T_1 = 50^0\text{C}$$

Now, Entropy generation

$$d_S = \frac{dQ}{T}$$

$$d_S = \frac{Q}{T_1} - \frac{Q}{T_2}$$

$$d_S = \frac{4.5\times10^3}{323} - \frac{4.5\times10^3}{353}$$

$$d_S = 1.184\ \text{W/m}^2 - \text{k}$$

Hence, the correct answer is 1.184.

Question 51

In a steam power plant based on Rankine cycle, steam is initially expanded in a high-pressure turbine. The steam is then reheated in a reheater and finally expanded in a low-pressure turbine. The expansion work in the high-pressure turbine is 400 kJ/kg and in the low-pressure turbine is 850 kJ/kg, whereas the pump work is 15 kJ/kg. If the cycle efficiency is 32%, the heat rejected in the condenser is ________ kJ/kg (round off to 2 decimal places).

Ans. **2624.375**

Sol. Given: -

Work of turbine $(w_t) = 400\,\text{kJ/kg}$

Pump work $(w_p) = 15\,\text{kJ/kg}$

Cycle efficiency $\eta_{rankine} = 32\%$

Work of turbine in (low pressure) $= 850$ kJ/kg

$$\eta = \frac{w_T - w_p}{Q_{add}}$$

$$0.32 = \frac{(850+400)-15}{Q_{add}}$$

$$Q_{add} = 3859.37 \text{ kJ/kg}$$

$$\eta = 1 - \frac{Q_{rejected}}{Q_{added}}$$

$$0.32 = 1 - \frac{Q_{rejected}}{Q_{added}}$$

$$0.68 \times 3859.375 = Q_{rejected}$$

$$Q_{rej} = 2624.375 \text{ kJ/kg}$$

Hence, the correct answer is 2624.375

Question 52

An engine running on an air standard Otto cycle has a displacement volume 250 cm^3 and a clearance volume 35.7 cm^3. The pressure and temperature at the beginning of the compression process are 100 kPa and 300 K, respectively. Heat transfer during constant-volume heat addition process is 800 kJ/kg. The specific heat at constant volume is 0.718 kJ/kg.K and the ratio of specific heats at constant pressure and constant volume is 1.4. Assume the specific heats to remain constant during the cycle. The maximum pressure in the cycle is ______ kPa (round off to the nearest integer).

Ans. **4809.17**

Sol. **Given :**

Displacement Volume $(V_S) = 250 \text{ cm}^3$

Clearance Volume $(V_C) = 35.7 \text{ cm}^3$

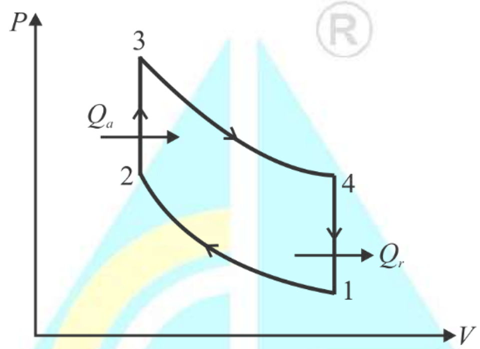
Initial pressure $(P_1) = 100$ kPa

Initial temperature $(T_1) = 300$ K

Heat addition at constant volume $(Q_a) = 800$ kJ/kg

Specific heat at constant volume $(C_V) = 0.718$ kJ/kg

$$\gamma = \frac{C_P}{C_V} = 1.4$$



Process 1-2 : Isentropic compression

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \text{ or } r^{\gamma-1}$$

Also,

$$\text{Compression ratio } (r) = \frac{V_1}{V_2} = 1 + \frac{V_S}{V_C} = 1 + \frac{250}{35.7} = 8$$

Using,
$$\frac{T_2}{T_1} = r^{\gamma-1} \Rightarrow \frac{T_2}{300} = 8^{1.4-1}$$

$$T_2 = 689.21 \text{ K}$$

$$\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r^{\gamma-1}$$

$$\left(\frac{P_2}{100}\right)^{\frac{1.4-1}{1.4}} = 8^{1.4-1}$$

$$P_2 = 1837.917 \text{ kPa}$$

For Process 2-3 : Heat addition at constant volume

$$(Q_a) = C_V(T_3 - T_2)$$

$$800 = 0.718 \times (T_3 - 689.21)$$

$$T_3 = 1803.416 \text{ K}$$

Also,

$$\frac{P_3}{P_2} = \frac{T_3}{T_2} \qquad \text{[for constant volume process]}$$

$$\frac{P_3}{1837.917} = \frac{1803.416}{689.21}$$

Maximum pressure $= P_3 = 4809.17$ kPa

Hence, the correct answer is 4809.17

Question 53

A steady two-dimensional flow field is specified by the stream function $\psi = kx^3y$, where x and y are in meter and the constant $k = 1\,\text{m}^{-2}\text{s}^{-1}$. The magnitude of acceleration at a point (x, y) = (1 m, 1 m) is ________ m/s^2 (round off to 2 decimal places).

Ans. **4.2426**

Sol. $\psi = Kx^3y$ – stream function is Given

$$u = \frac{-\partial\psi}{\partial y} = -Kx^3$$

$$v = \frac{+\partial\psi}{\partial x} = 3Kx^2y$$

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

$$K = 1, x = 1, y = 1$$

$$a_x = (-Kx^3)\times(-3Kx^2) = (-1)(-3)$$

$$= 3 \text{ unit}$$

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

$$= (-Kx^3)(6Kxy) + 3Kx^2y(3Kx^2)$$

$$= (-1)(6) + 9 = 3 \text{ unit}$$

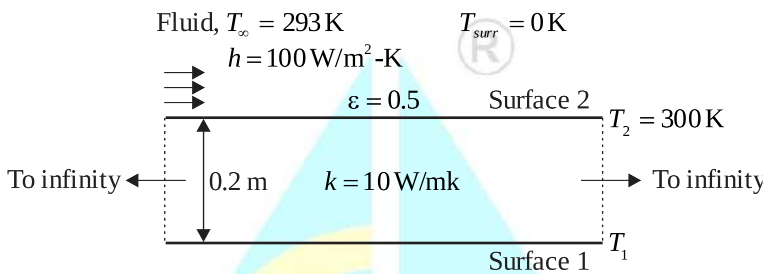
$$a_t = \sqrt{ax^2 + ay^2}$$

$$a_{total} = \sqrt{9+9} = \sqrt{18} = 4.2426 \text{ unit}$$

Hence, the correct answer is 4.2426.

Question 54

Consider a solid slab (thermal conductivity, $k = 10\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$) with thickness 0.2 m and of infinite extent in the other two directions as shown in the figure. Surface **2**, at 300 K, is exposed to a fluid flow at a free stream temperature (T_∞) of 293 K, with a convective heat transfer coefficient (h) of $100\ \mathrm{W \cdot m^{-2} \cdot K^{-1}}$. Surface **2** is opaque, diffuse and gray with an emissivity (ε) of 0.5 and exchanges heat by radiation with very large surroundings at 0 K. Radiative heat transfer inside the solid slab is neglected. The Stefan-Boltzmann constant is $5.67 \times 10^{-8}\ \mathrm{W \cdot m^{-2} \cdot K^{-4}}$. The temperature T_1 of Surface **1** of the slab, under steady-state conditions, is _________ K (round off to the nearest integer).



Ans. **318.59**

Sol. Given:-

Thermal conductivity $(k) = 10\ \mathrm{W/mk}$

Thickness $(L) = 0.2\ \mathrm{m}$

Temperature at surface (2) $(T_2) = 300\ \mathrm{k}$

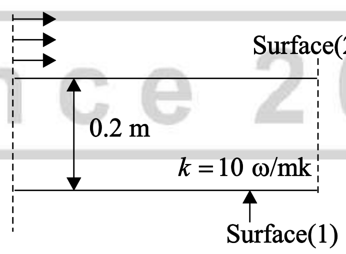
Heat transfer coefficient $(h) = 100\ \mathrm{W/m^2}$

Emissivity of surface (2) $(\varepsilon) = 0.5$

Surrounding temperature $(T_\infty) = 293\mathrm{k}$

Temperature of large surrounding $(T_{\text{large}}) = 0\mathrm{k}$

Stefan boltzman constant $(\sigma) = 5.67 \times 10^{-8}\ \mathrm{w/m^2k^4}$



$$Q_{convection} = Q_{conduction} + Q_{rudiation}$$

$$\frac{kA(T_1 - T_2)}{L} = hA(T_2 - T_\infty) + \varepsilon\sigma A[T_2^4 - T_{\text{large}}^4]$$

$$\frac{10 \times (T_1 - 300)}{0.2} = 100 \times (300 - 293) + 0.5 \times 5.67 \times 10^{-8}[300^4 - 0^4]$$

$$t_1 = 318.59 \text{ k}$$

Hence, the correct answer is 318.59 k.

Question 55

During open-heart surgery, a patient's blood is cooled down to 25^0C from 37^0C using a concentric tube counter-flow heat exchanger. Water enters the heat exchanger at 4^0 C and leaves at 18^0 C. Blood flow rate during the surgery is 5 L/minute.

Use the following fluid properties:

Fluid	Density (kg/m^3)	Specific heat (J/kg-K)
Blood	1050	3740
Water	1000	4200

Effectiveness of the heat exchanger is ________ (round off to 2 decimal places).

Ans. **0.4242**

Sol. Inlet temperature of hot fluid $(T_{h_i}) = 37^0\text{C}$

Outlet temperature of hot fluid $(T_{h_e}) = 25^0\text{C}$

Inlet temperature of cold fluid $(T_{C_i}) = 4^0\text{C}$

Outlet temperature of cold fluid $(T_{C_e}) = 18^0\text{C}$

Effectiveness $(\in)$

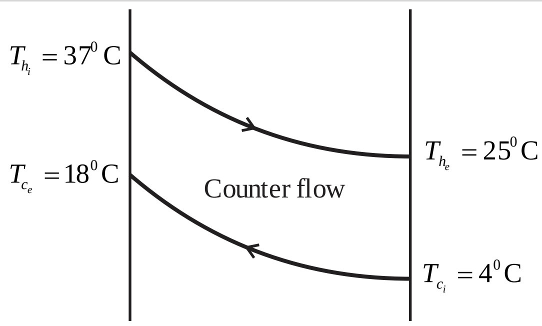
$$\in = \frac{C_c(t_{c_2} - t_{c_1})}{C_{\min}(T_{h_1} - T_{C_1})}$$

$$\dot{m}_h = \frac{5\times10^{-3}}{60}\times 1050 = 0.0875 \text{ kg/sec}$$

$$\dot{m}_h C_h (T_{h_i} - T_{h_e}) = \dot{m}_c C_c (T_{c_e} - T_{c_i})$$

$$0.0875\times3740\times12 = \dot{m}_c \times 4200\times14$$

$$\dot{m}_c = 0.667$$



$$C_c = C_{\min}$$

$$\in = \frac{18-4}{37-4} = 0.4242$$

Hence, the correct answer is 0.4242.