BYJU'S EXAM PREP

GATE 2021

Set-2

Mechanical Engineering

Questions & Solutions

SECTION: GENERAL APTITUDE

1. The world is going through the worst pandemic in the past hundred years. The air travel industry is facing a crisis, as the resulting quarantine requirement for travelers led to weak demand.

In relation to the first sentence above, what does the second sentence do?

A. Restates an idea from the first sentence.

B. Second sentence entirely contradicts the first sentence.

C. The two statements are unrelated.

D. States an effect of the first sentence

Ans. D

Sol.

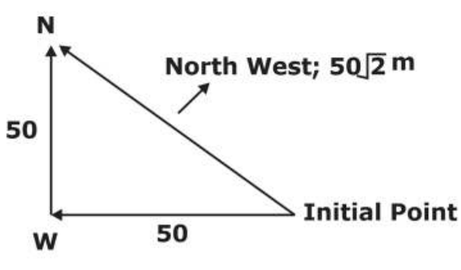
2. The front door of Mr. X's house faces East. Mr. X leaves the house, walking 50 m straight from the back door that is situated directly opposite to the front door. He then turns to his right, walks for another 50 m and stops. The direction of the point Mr. X is now located at with respect to the starting point is ___________.

A. South-East B. North-West

C. North-East D. West

Ans. B

Sol.



3. A box contains 15 blue balls and 45 black balls. If 2 balls are selected randomly, without replacement, the probability of an outcome in which the first selected is a blue ball and the second selected is a black ball, is ________.

A. $\frac{3}{4}$ B. $\frac{45}{236}$

C. $\frac{3}{16}$ D. $\frac{1}{4}$

Ans. B

Sol. First Blue then Black

$$P = \frac{^{15}C_1}{^{60}C_1} \times \frac{^{45}C_1}{^{59}C_1} = \frac{15}{60} \times \frac{45}{59} = \frac{45}{236}$$

4. If $\oplus \div \odot = 2;\ \oplus \div \Delta = 3;\ \odot + \Delta = 5;\ \Delta \times \otimes = 10$.

Then, the value of $(\otimes - \oplus)^2$, is________.

A. 1 B. 0

C. 16 D. 4

Ans. A

Sol. If $\oplus \div \odot = 2;\ \oplus \div \Delta = 3; \odot + \Delta = 5;\ \Delta \times \otimes = 10$

$$\oplus \div \odot = 2; \Rightarrow \odot = x \,\&\, \oplus = 2x$$

$$\oplus \div \Delta = 3 \Rightarrow 2x \div \Delta = 3 \Rightarrow \Delta = \frac{2x}{3}$$

$$\odot + \Delta = 5 \Rightarrow x + \frac{2x}{3} = 5 \Rightarrow x = 3$$

$$\Delta \times \otimes = 10 \Rightarrow \frac{2x}{3} \times \otimes = 10 \Rightarrow \otimes = 5$$

$$\odot = x = 3, \oplus = 2x = 6, \Delta = \frac{2x}{3} = 2, \otimes = 5$$

$$(\otimes - \oplus)^2 = (5-6)^2 = 1$$

5. Five persons P, Q, R, S and T are to be seated in a row, all facing the same direction but not necessarily in the same order. P and T cannot be seated at either end of the row. P should not be seated adjacent to S.R is to be seated at the second position from the left end of the row. The number of distinct seating arrangements possible is:

A. 4 B. 3

C. 5 D. 2

Ans. B

Sol. The possible arrangements for the seating are given below

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

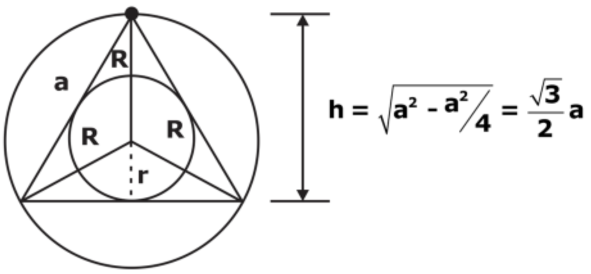
6. The ratio of the area of the inscribed circle to the area of the circumscribed circle of an equilateral triangle is _________.

A. $\frac{1}{6}$ B. $\frac{1}{2}$

C. $\frac{1}{8}$ D. $\frac{1}{4}$

Ans. D

Sol.



$$R + r = h = \frac{\sqrt{3}}{2}a$$

$$r^2 + \frac{a^2}{4} = R^2$$

$$\left(\frac{\sqrt{3}}{2}a - R\right)^2 + \frac{a^2}{4} = R^2$$

$$\frac{3}{4}a^2 + R^2 - \sqrt{3}\,aR + \frac{a^2}{4} = R^2$$

$$a^2 = \sqrt{3}aR$$

$$a = \sqrt{3}R$$

$$R = \frac{1}{\sqrt{3}}a$$

$$r = \frac{\sqrt{3}}{2}a - \frac{1}{\sqrt{3}}a = \frac{a}{2\sqrt{3}}$$

$$\frac{A_{inner}}{A_{outer}} = \frac{\pi r^2}{\pi R^2} = \frac{\frac{a^2}{12}}{\frac{a^2}{3}} = \frac{3}{12} = \frac{1}{4}$$

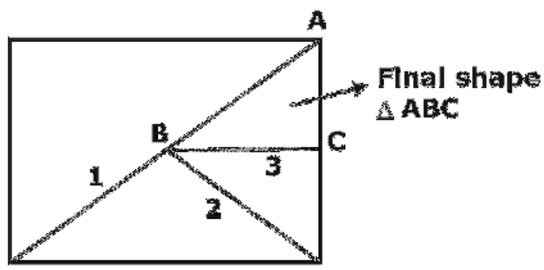
7. Consider a square sheet of side 1 unit. The sheet is first folded along the main diagonal. This is followed by a fold along its line of symmetry. The resulting folded shape is again folded along its line of symmetry. The area of each face of the final folded shape, in square units equal to ______.

A. $\frac{1}{4}$ B. $\frac{1}{16}$

C. $\frac{1}{32}$ D. $\frac{1}{8}$

Ans. D

Sol. Initial area of the square = 1



Final area will be the 1/8th part of initial area, thus Answer will be D.

8. A digital watch X beeps every 30 seconds while watch Y beeps every 32 seconds. They beeped together at 10 AM. The immediate next time that they will beep together is ________.

A. 10.00 PM B. 10.08 AM.

C. 11.00 AM D. 10.42 AM

Ans. B

Sol. LCM (30, 32) = 2 × 2 × 8 × 3 × 5

= 2 × 16 × 15 = 480

480 sec = 8 min

Show the time is 10: 08 AM.

9. Given below are two statement 1 and 2, and two conclusions I and II.

Statement 1: All entrepreneurs are wealthy.

Statement 2: All wealthy are risk seekers.

Conclusion I: All risk seekers are wealthy.

Conclusion II: Only some entrepreneurs are risk seekers.

Based on the above statements and conclusions, which one of the following options is CORRECT?

A. Neither conclusion I nor II is correct

B. Only conclusion II is correct

C. Both conclusions I and II are correct

D. Only conclusion I is correct

Ans. A

Sol.

10. Consider the following sentences:

A. The number of candidates who appear for the GATE examination is staggering.

B. A number of candidates from my class are appearing for the GATE examination.

C. The number of candidates who appear who appear for the GATE examination are staggering.

D. A number of candidates from my class is appearing for the GATE examination.

Which of the above sentences are grammatically CORRECT?

A. (i) and (ii)

B. (i) and (iii)

C. (ii) and (iii)

D. (ii) and (iv)

Ans. A

Sol.

MECHANICAL ENGINEERING

1. Which of the following is responsible for eddy viscosity (or turbulent viscosity) in a turbulent boundary layer over a flat plate.

A. Nikuradse stresses

B. Prandtl stresses

C. Reynolds stresses

D. Boussinesq stresses

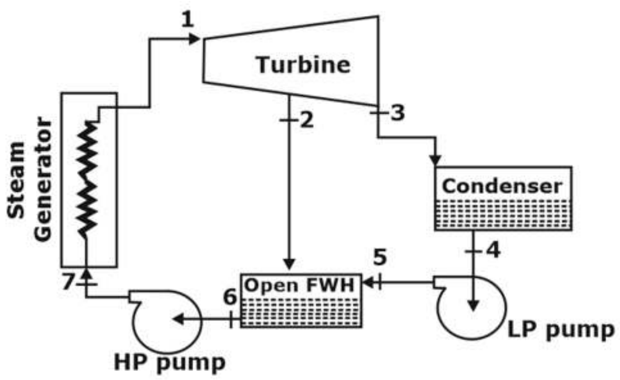
Ans. C

Sol.

- Reynolds stresses is responsible for eddy viscosity (or turbulent viscosity) in a turbulent boundary layer over a flat plate.

2. Consider the open feed water heater (FWH) shown in the figure given below:

is 2624 kJ/kg. specific enthalpy of water at location 5 is 226.7 kJ/kg and specific enthalpy of saturated water at location 6 is 708.6 kJ/kg. If the mass flow rate of water entering the open feed water heater (at location 5) is 100 kg/s then the mass flow rate of steam at location 2 will be kg/s (round off to one decimal place).



Ans. 25.15kg/s

Sol. Given,

h_2 = 2624kJ/kg

h_5 = 226.7 kJ/kg

h_6 = 708.6kJ/kg

m_w = 100kg/s

By applying mass balance.

$m_{total} = m_s + m_w$

By applying mass balance.

$m_s h_2 + m_w h_5 = (m_s + m_w) h_6$

$$m_s = m_w\left(\frac{h_6 - h_5}{h_2 - h_6}\right)$$

$$m_s = 100 \times \left(\frac{708.6 - 226.7}{2624 - 708.6}\right)$$

m_s = 25.15kg/s

3. The value of $\int_0^{\frac{\pi}{2}} \int_0^{\cos\theta} r\sin\theta dr d\theta$ is

A. π

B. 0

C. $\frac{1}{6}$

D. $\frac{4}{3}$

Ans. C

Sol. $I = \int_0^{\frac{\pi}{2}} \int_0^{\cos\theta} r\sin\theta dr d\theta$

$$I = \int_0^{\frac{\pi}{2}} \left[\frac{r^2}{2}\right]_0^{\cos\theta} \sin\theta d\theta$$

$$I = \frac{1}{2}\int_0^{\pi/2} \left(\cos^2\theta - 0\right)\sin\theta d\theta$$

$$I = \frac{1}{2}\int_0^{\pi/2} \left(1 - \sin^2\theta\right)\sin\theta d\theta$$

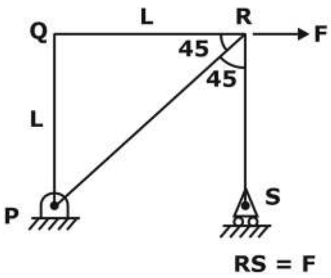
$$= \frac{1}{2}\int_0^{\pi/2} \left(\sin\theta - \sin^3\theta\right) d\theta$$

$$I = \frac{1}{2}\left[\left(-\cos\theta\right)_0^{\frac{\pi}{2}} - \int_0^{\pi/2} \sin^3\theta d\theta\right]$$

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

$$I = \frac{1}{2}\times\frac{1}{3} = \frac{1}{6}$$

4. A Plane truss PQRS ($PQ = RS$ & $\angle PQR = 90°$) is shown in figure.



The forces in the members PR and RS respectively, are

A. $F\sqrt{2}$ (tensile) and F (tensile)

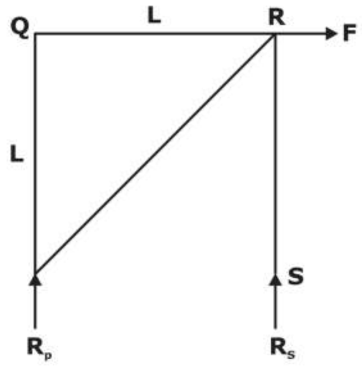
B. F (tensile) and $F\sqrt{2}$ (tensile)

C. F (Compressive) and $F\sqrt{2}$ (compressive)

D. $F\sqrt{2}$ (tensile) and F (compressive)

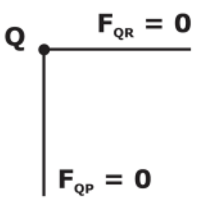
Ans. D

Sol.

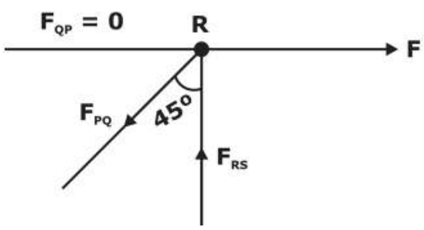


$F_{PR} = ?$ and $F_{RS} = ?$

FBD at Q



FBD at R



By Lami's theorem

$$\frac{F_{PQ}}{\sin 90^{\circ}} = \frac{F}{\sin 45^{\circ}} = \frac{F_{RS}}{\sin 135^{\circ}}$$

$$F_{PQ} = \sqrt{2}\,F\,(\text{Tensile})$$

$$F_{rs} = F\,(\text{Comp.})$$

5. The demand and forecast of an item for five months are given in the table.

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

The Mean Absolute Percent Error (MAPE) in the forecast is ____________%

(round off to two decimal places)

Ans. 8.07

Sol.

Month	Demand, d	Forecast, F	Absolute percentage error, $\left\lvert\frac{D_i - F_i}{D_i}\right\rvert \times 100$
April	225	200	11.11
May	220	240	9.09
June	285	300	5.26
July	290	270	6.9
August	250	230	8

mean Absolute percentage error

$$= \frac{\left\lvert\frac{D_i - F_i}{D_i}\right\rvert \times 100}{n}$$

$$\text{MAPE} = \frac{11.11 + 9.09 + 5.26 + 6.9 + 8}{5}$$

$$= 8.072$$

6. A column with one end fix and other end free is having a buckling load of 100N. For the same column if the free end is replaced by with a pinned end then the critical buckling load will be ....N (round off to the nearest integer)

Ans. 800

Sol. Case -1 one end fix and other end free

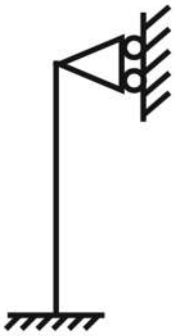
$l_e = 2l$

$$P_e = \frac{\pi^2 E I_{min}}{L_e^2}$$

$$P_e = \frac{\pi^2 E I_{min}}{(2L)^2} = 100$$

$$\frac{\pi^2 E I_{min}}{L^2} = 400$$

Case -2 Free end is replaced with pinned end.



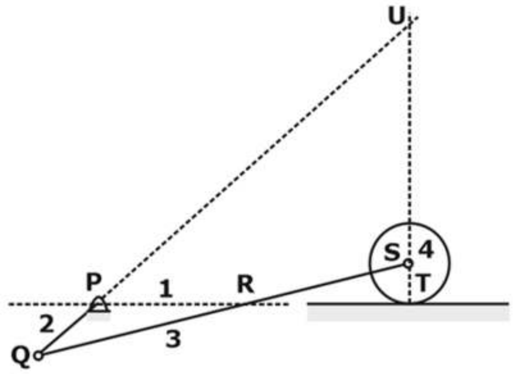
$$L_e = \frac{L}{\sqrt{2}}$$

$$P_e = \frac{\pi^2 E I_{min}}{L_e^2}$$

$$P_e = \frac{\pi^2 E I_{min}}{\left(\frac{L}{\sqrt{2}}\right)^2} = 2 \times \frac{\pi^2 E I_{min}}{L^2}$$

$$P_e = 2 \times 400 = 800N$$

7. Consider the mechanism shown in the figure. There is rolling without slip between the disc and the ground.



Select the correct statement about Instantaneous Centre in the mechanism.

A. Only points P, Q, S and T are Instantaneous Centre of Mechanism

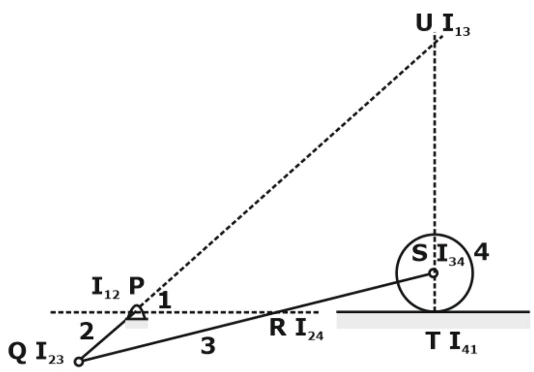
B. Only points P, Q, R, S, T and U are Instantaneous Centre of Mechanism

C. Only points P, Q, and S are Instantaneous Centre of Mechanism

D. Only points P, Q, R, S and U are Instantaneous Centre of Mechanism

Ans. B

Sol. Mechanism with all Instantaneous Centre are drawn below, and from there it can be concluded that all the points P,Q ,R, S,T & U are the Instantaneous Centre of the mechanism.



8. Consider an n x n matrix A and a non-zero n × 1 vector p. Their product Ap = α^2p. where α^2p where $\alpha \in R$ and $\alpha \notin (-1,0,1)$. Based on the given information, the eigen value of A^2 is:

A. α B. $\sqrt{\alpha}$

C. α^4 D. α^2

Ans. C

Sol. $A_{n\times n}$ = Transformation matrix

$P_{n\times 1}$ = Invariant matrix

Given,

AP = α^2P

Comparing it with AX = λX

$$X = P\begin{bmatrix} \\ \\ \end{bmatrix}_{n\times 1} = \text{eigen vector}$$

λ = α^2 = eigen values of matrix A

eigen values of matrix $A^2 = \lambda^2 = \alpha^4$

9. For a two – dimensional, incompressible flow having velocity components u an v in the x & y direction respectively, the expression,

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

Can be simplified to

A. $2u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}$ B. $2u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}$

C. $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}$ D. $u\frac{\partial u}{\partial x}+u\frac{\partial v}{\partial y}$

Ans. C

Sol. For given equation of fluid flow,

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

$$\Rightarrow 2u\frac{\partial u}{\partial x}+u\frac{\partial v}{\partial y}+v\frac{\partial u}{\partial y}$$

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

$$\Rightarrow u\frac{\partial u}{\partial x}+u\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)+v\frac{\partial u}{\partial y}$$

For incompressible flow,

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

$$u\frac{\partial u}{\partial x}+u(0)+v\frac{\partial u}{\partial y}$$

$$\frac{\partial}{\partial x}(u^2)+\frac{\partial}{\partial y}(uv)=u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}$$

10. Ambient pressure, temperature and relative humidity at a location are 101kPa and 300K and 60% respectively. The saturation pressure of water at 300K is 3.6 kPa. The specific humidity of ambient air is ....g/kg of dray air.

A. 21.4

B. 35.1

C. 13.6

D. 21.9

Ans. C

Sol. Given,

Sat

saturation pressure of water at 300K , P_{vs} = 3.6 kPa

Relative humidity, φ = 60%

$$\phi=\frac{p_v}{p_{vs}}$$

$$0.6=\frac{p_v}{3.6}\Rightarrow P_v=2.16\text{kPa}$$

Specific humidity of air is given as

$$\omega=0.622\frac{p_v}{p-p_v}$$

$$\omega=0.622\times\frac{2.16}{101-2.16}$$

ω = 0.01359 kg/kg of dry air

ω = 13.59 g/kg of dry air = 13.6 g/kg of dry air

11. The allowance provided in between a hole and a shaft is calculated from the difference between

A. lower limit of the shaft and the upper limit of the hole

B. upper limit of the shaft and the upper limit of the hole

C. upper limit of the shaft and the lower limit of the hole

D. lower limit of the shaft and the lower limit of the hole

Ans. C

Allowance is defined as the minimum clearance between the shaft and the hole.

Thus, it is difference of upper limit of shaft and lower limit of hole

12. A factory produces m (i = 1,2, ... ,m) products, each of which requires processing on n (j = 1,2, ... , n) workstations. Let a_{ij} be the amount of processing time that one unit of the i^{th} product requires on the j^{th} workstation. Let the revenue from selling one unit of the i^{th} product be r_i and h_i be the holding cost per unit per time period for the i^{th} product. The planning horizon consists of T (t = 1,2, ... , T) time periods. The minimum demand that must be satisfied in time period t is d_{it}. and the capacity of the j^{th} workstation in time period t is c^{jt}. Consider the aggregate planning formulation below, with decision variables S_{it} (amount of product i sold in time period t). X_{it} (amount of product i manufactured in time period t) and I_{it} (amount of product i held in inventory at the end of time period t).

$$\max \sum_{t=1}^{T}\sum_{i=1}^{m}(r_i S_{it} - h_i I_{it})$$

subject to

$S_{it} > d_{it}$ V i,t

< capacity constraint >

< inventory balance constraint >

X_{it}, S_{it}, $I_{it} \ge 0$; $I_{i0} = 0$

The capacity constraints and inventory balance constraints for this formulation respectively are

A. $\sum_{i}^{m} a_{ij}X_{it} \le c_{jt}\ \forall\ i,t$ and $I_{it} = I_{i,t-1} + X_{it} - d_{it}\ \forall\ i,t$

B. $\sum_{i}^{m} a_{ij}X_{it} \le c_{jt}\ \forall\ j,t$ and $I_{it} = I_{i,t-1} + X_{it} - S_{it}\ \forall\ i,t$

C. $\sum_{i}^{m} a_{ij}X_{it} \le d_{jt}\ \forall\ i,t$ and $I_{it} = I_{i,t-1} + X_{it} - S_{it}\ \forall\ i,t$

D. $\sum_{i}^{m} a_{ij}X_{it} \le d_{jt}\ \forall\ i,t$ and $I_{it} = I_{i,t-1} + S_{it} - X_{it}\ \forall\ i,t$

Ans. B

Sol. Let,

$X_{ij} \rightarrow$ No. of units produces of i^{th} produce in 't' period [I = 1, 2 …….. m]

$a_{ij} \rightarrow$ Processing time of i^{th} job on j^{th} workstation.

$I_{it} \rightarrow$ No. of units of i^{th} product shared in t^{th} period.

$d_{it} \rightarrow$ Minimum demons of i^{th} product on t^{th} period.

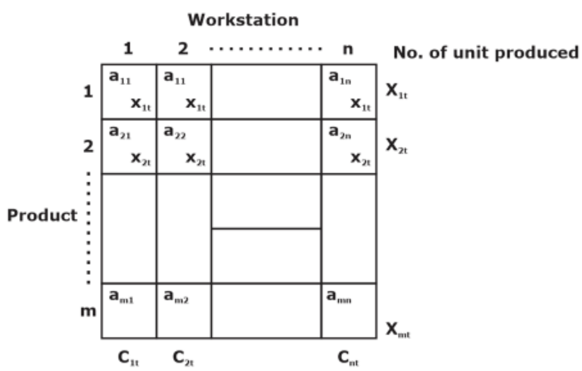
$S_{it} \rightarrow$ No. of units sold in i^{th} product in t^{th} period.

$C_{it} \rightarrow$ Capacity of i^{th} workstation on t^{th} period.

$r_i \rightarrow$ selling price of i^{th} product.

$h_i \rightarrow$ Holding cost of i^{th} product.

Allocation Table



Capacity of workstation

LLP is objective function

$$Z_{increase} = \sum_{t=1}^{T}\ \sum_{i=1}^{m}\left(r_i\, S_{ij}\, h_i\, I_{it}\right)$$

STC

$S_{ij} \geq d_{ij}$

Min. requirement

of i^{th} product.

$\sum_{i=1}^{m} a_{ij} a_{it} \leq C_{jt}$

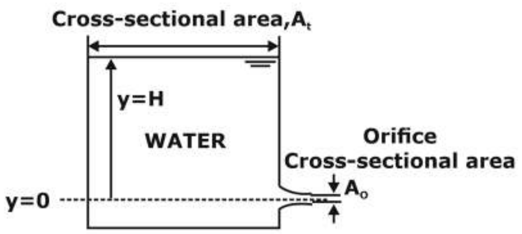
$\forall,\ \partial,\ t$ (capacity constant r_{air} t)

$I_{it} = I_{i(t-1)} + X_{it} S_{it}$

(Inventory balance constant)

$X_{it},\ S_{it},\ I_{it} \geq 0,\ I_{i0} = 0$

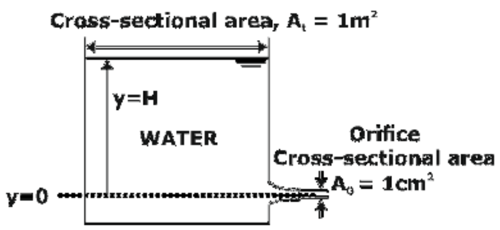
13. Water flows out from a large tank of cross-sectional area A_t = 1 m^2 through a small rounded orifice of cross-sectional area A_0 = 1 cm^2, located at y = 0. Initially the water level (H), measured from y = 0. is 1 m. The acceleration due to gravity is 9.8 m/s^2.



Neglecting any losses, the time taken by water in the tank to reach a level of y = H/4 is seconds (round off to one decimal place).

Ans. 2257.61

Sol.



Given,

H_1 = 1m

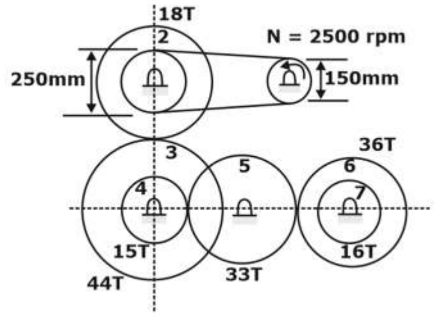
H_2 = 0.25m

$$T = \frac{2A_t \times \left(\sqrt{H_1} - \sqrt{H_2}\right)}{A_0 \times \sqrt{2g}}$$

$$T = \frac{2 \times 1 \times \left(\sqrt{1} - \sqrt{0.25}\right)}{1 \times 10^{-4} \times \sqrt{2 \times 9.81}}$$

T = 2257.61s

14. A power transmission mechanism consists of a belt drive and a gear train as shown in the figure.



Diameters of pulleys of belt drive and number of teeth (T) on the gears 2 to 7 are indicated in the figure. The speed and direction of rotation of gear 7. respectively. are

A. 255.68 rpm: clockwise

B. 575.28 rpm: clockwise

C. 575.28 spin: anticlockwise

D. 255.68 spin: anticlockwise

Ans. A

Sol. Given,

T_2	T_3	T_4	T_5	T_6	T_7
18	44	15	33	16	36
Anti-clockwise	Clock-wise	Clock-wise	Anti-clockwise	Clock-wise	Clock-wise

Here, smaller pulley is rotating in clockwise direction with a speed of 2500 RPM.

Thus, speed of larger pulley,

For belt drive,

$N_1D_1 = N_2D_2$

$2500\times 150 = 250 \times N_2$

$N_2 = 1500$RPM

Since, larger pulley and gear 2 is mounted on same shaft thus speed of gear 2 will be 1500RPM.

Now, from Train value,

$$\frac{N_6}{N_2} = \frac{T_2 \times T_4 \times T_5}{T_3 \times T_5 \times T_6}$$

$$\frac{N_6}{1500} = \frac{18 \times 15 \times 33}{44 \times 33 \times 36}$$

$N_6 = 255.68$RPM

Since, Gear 6 & 7 mounted on same shaft thus speed of gear 7 will be same as that of Gear 6.

15. Value of $(1+i)^8$ where $i = \sqrt{-1}$ is equal to

A. 16 B. 16i

C. 4i D. 4

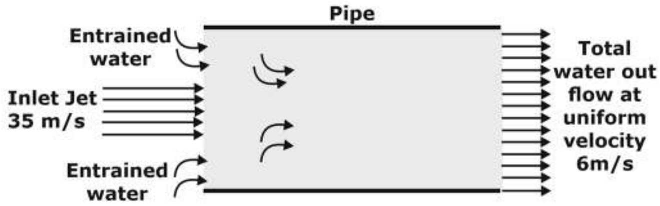
Ans. A

Sol. $(1+i)^8 = \left[(1+i)^2\right]^4 = \left(1+i^2+2i\right)^4$

As we know, $i^2 = -1$

$(1+i)^8 = (2i)^4 = 16i^4 = 16 \quad (i^4 = 1)$

16. A high velocity water jet of cross section area $= 0.01\ m^2$ and velocity = 35m/s enters a pipe filled with stagnant water. The diameter of the pipe is 0.32 m. This high velocity water jet entrains additional water front the pipe and the total water leaves the pipe with a velocity 6 m/s as shown in the figure.



The flow rate of entrained water is litre/s (round off to two decimal places).

Ans. 132.5

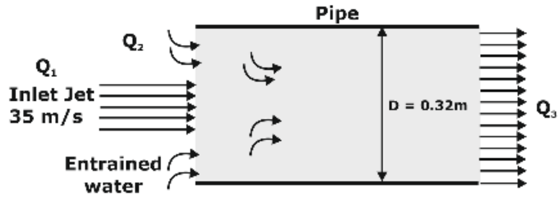
Sol. Given,

Diameter of the pipe = 0.32m

cross section area of water jet

$= 0.01\ m^2$

Velocity of water jet, V = 35m/s



From the continuity equation

$Q_1 + Q_2 = Q_3$

$Q_2 = Q_3 - Q_1$

$$Q_2 = \frac{\pi}{4} \times 0.32^2 \times 6 - 0.01 \times 35$$

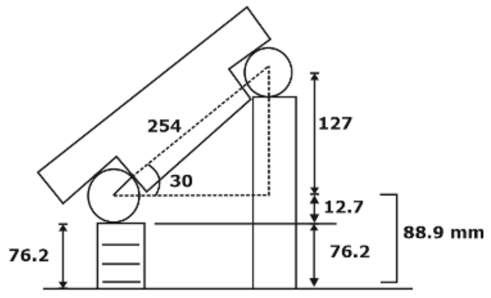
$$Q_2 = 0.1325 m^3 / s$$

$$Q_2 = 132.5 l / s$$

17. A 76.2 mm gauge block is used under one end of a 254 mm sine bar with roll diameter of 25.4 mm. The height of gauge blocks required at the other end of the sine bar to measure an angle of 30° is ________ mm (round off to two decimal places).

Ans. 203.2

Sol.



From the figure,

$$\sin 30^\circ = \frac{x}{254} \Rightarrow x = 127$$

So height of the slip gauge will be = 127 + 12.7 + 76.2 -12.7 = 203.2mm

18. Daily production capacity of a bearing manufacturing company is 30000 bearings. The daily demand of the bearing is 15000. The holding cost per year of keeping a bearing in the inventory is Rs. 20. The setup cost for the production of a batch is Rs. 1800. Assuming 300 working days in a year. the economic batch quantity in number of bearings is _______ (in integer).

Ans.

Sol. 40249

Given that

p = 30,000 unit/day

d = 15,000 units/day

C_h = 20 ₹/unit/yr

C_o = 1800 ₹/Setup

Number of days in a year, n = 300

EOQ for finite replenishment rate

$$Q^* = \sqrt{\frac{2DC_o}{C_h} \times \frac{p}{p-d}} \qquad (\because D = n \times d)$$

$$\therefore Q^* = \sqrt{\frac{2 \times 300 \times 15000 \times 1800}{20} \times \frac{30000}{30000-15000}}$$

Q* = 40249.22 units =40249 units

19. A vertical shaft Francis turbine rotates at 300 rpm. The available head at the inlet to the turbine is 200 m. The tip speed of the rotor is 40 m/s. Water leaves the runner of the turbine without whirl. Velocity at the exit of the draft tube is 3.5 m/s. The head losses in different components of the turbine are: (i) stator and guide vanes: 5 m (ii) rotor: 10 m. and (iii) draft tube: 2 m. Flow rate through the turbine is 20 m^3/s. Take g = 9.8 m/s^2. The hydraulic efficiency of the turbine is __________ % (round off to one decimal place).

Ans. 91.18

Sol. Given,

Francis turbine

Rotational speed, N = 300 rpm

Available heat at inlet H_{net} = 200 m

Tip speed of the rotor velocity, u = 40 m/s

Whirl velocity at the outlet, $V_{w_2} = 0$

Velocity at exit of the draft tube, V_3 = 3.5 m/sec

Head losses in

Stator + Guide vane = 5 m

In rotor = 10 m

In draft tube = 2 m

Total loss = 5 + 10 + 2 = 17m

Flow rate, Q = 20 m^3/sec

$$H_{net} = \frac{V_{w_1}u_1}{g} + \frac{(V_{exit})^2}{2g} + \text{Losses}$$

$$200 = \frac{V_{w_1} \times u_1}{g} + \frac{3.5^2}{2g} + 17$$

$$\frac{V_{w_1} \times u_1}{g} = 182.375$$

$$\eta_{hydraulic} = \frac{\frac{V_{w_1} \times u_1}{g}}{H_{net}}$$

$$\eta_{hydraulic} = \frac{182.375}{200} = 0.9118 = 91.18\%$$

20. Let the superscript T represent the transpose operation. Consider the function

$f(x) = \frac{1}{2}x^T Qx - r^T x$, where x and r are n × 1 vectors and Q is a symmetric it n × n matrix. The stationary point of f(x) is

A. $Q^{-1}r$
B. $Q^T r$
C. $\frac{r}{r^T r}$
D. r

Ans. A

Sol. $Q = \begin{bmatrix} a & c \\ c & b \end{bmatrix}$, $X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$, $R = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$

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

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

$$U(x_1, x_2) = \frac{1}{2}ax_1^2 + \frac{1}{2}bx_2^2 + cx_1x_2 - r_1x_1 - r_2x_2$$

For critical point,

$$\frac{\partial U}{\partial x_1} = 0, \frac{\partial U}{\partial x_2} = 0$$

$ax_1 + cx_2 - r_1 = 0$

$bx_2 + cx_1 - r_2 = 0$

above equation can be rewritten as,

$$\begin{bmatrix} a & c \\ c & b \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$$

QX = R

$X = Q^{-1}R$

21. Ambient air flows over a heated slab having flat. top surface at y = 0. The local temperature (in Kelvin) profile within the thermal boundary layer is given by T(y) = 300 + 200 exp(-5y). where y is the distance measured from the slab surface in meters. If the thermal conductivity of air is A.0 W/m-K and that of the slab is 100 W/m-K, then the magnitude of temperature gradient $\left|\frac{dT}{dy}\right|$ within the slab at y = 0 is ___________ K/m (round off to the nearest integer).

Ans. 10

Sol. Given,

temperature profile within the thermal boundary layer

= T(y) = 300 + 200 exp(-5y)

$$\left.\frac{dT}{dy}\right|_{y=0} = \frac{d}{dy}(300 + 200e^{-5y})$$

$$\left.\frac{dT}{dy}\right|_{y=0} = -1000K/m$$

Now,

Heat conducted within the slab

= Heat conducted in air at Y = 0

$$\left[-k_f \left.\frac{dT}{dy}\right|_{y=0}\right]_{slab} = \left[-k_f \left.\frac{dT}{dy}\right|_{y=0}\right]_{air}$$

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

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

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

22. In forced convection heat transfer, Stanton number (St), Nusselt Number (Nu) , Reynolds number (Re) and prandtl number are related as

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

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

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

D. $St = Nu \times Pr \times Re$

Ans. B

Sol. Stanton number is the ratio of Nusselt number to peclet number.

peclet number is the product of Reynold number and Prandtl number.

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

$$St = \frac{h}{\rho V c_p}$$

23. Find the positive real root of $x^3 - x - 3 = 0$ using Newton – Raphson method. if the starting guess (x_0) is 2, The numerical value of the root after two iteration (x_2) is …… (round off to two decimal places)

Ans. 1.67

Sol. Given, $x^3 - x - 3 = 0$

$f(x) = x^3 - x - 3$

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

From the newton- Raphson,

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} = 2 - \frac{(2^3 - 2 - 3)}{3(2^2) - 1}$$

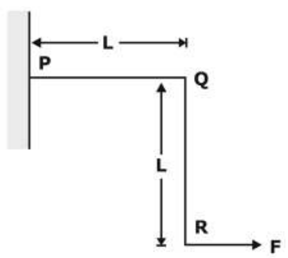
$$= 2 - \frac{3}{11} = 1.73$$

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)} = 1.73$$

$$- \frac{(1.73^3 - 1.75.3)}{3(1.73)^2 - 1}$$

$$x_2 = 1.73 - \frac{0.44}{7.9787} = 1.673$$

24. A plane frame PQR (fixed at P and free at R) is shown in the figure. Both members (PQ and QR) have length. L. and flexural rigidity. EI. Neglecting the effect of axial stress and transverse shear. the horizontal deflection at free end R is.



A. $\frac{FL^3}{3EI}$

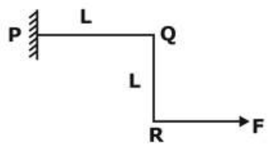
B. $\frac{4FL^3}{3EI}$

C. $\frac{2FL^3}{3EI}$

D. $\frac{5FL^3}{3EI}$

Ans. B

Sol.



Due to this Force F, there will be

$$\text{Total SE} = U = \int_0^L \frac{M_{QR}^2\,dx}{2EI} + \int_0^L \frac{M_{PQ}^2\,dx}{2EI}$$

$$= \int_0^L \frac{[Px]^2\,dx}{2EI} + \int_0^L \frac{[PL]^2\,dx}{2EI}$$

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

$$\text{Deflection at R} = \frac{\partial u}{\partial p} = \frac{4}{3}\frac{PL^3}{EI}$$

25. A cantilever beam with a uniform flexural rigidity ($EI = 200 \times 10^6$ N.m^2) is loaded with a concentrated force at its free end. The area of the bending moment diagram corresponding to the full length of the beam is 10000 N-m$^{8.}$ The magnitude of the slope of the beam at its free end is ………..micro radian (round off to the nearest integer).

Ans. 50

Sol.

Given.

$EI = 200 \times 10^6$ N – m^2

Area of BMD = 10000 Nm^2

From the modified mohr's theorem,

$\theta_A - \theta_B$ = Area of Bending moment diagram/ EI

$$\theta_A - \theta_B = \frac{10,000}{200 \times 10^6}$$

Since B is fixed end thus, $\theta_B = 0$

$\theta_A = 50 \times 10^{-6}$ radians

$\theta_A = 50$ micro radian

26. Consider an ideal vapour compression refrigeration cycle working on R-134a refrigerant. The COP of the cycle is 10 and the refrigeration capacity is 150 kJ/kg. The heat rejected by the refrigerant in the condenser is ……… kJ/kg (round off to the nearest integer).

Ans.

Sol. 165

Given,

COP of the cycle = 10

Refrigeration effect = 150kJ/kg

As we know.

Heat rejection ratio = $\frac{Q_R}{RE}$

$$\frac{Q_R}{RE} = 1 + \frac{1}{COP}$$

$$\frac{Q_R}{150} = 1 + \frac{1}{10}$$

$$\frac{Q_R}{150} = 1.1$$

Q_R = 165kJ/kg

27. A two-dimensional flow has velocities in x and y directions given by u = 2xyt and v = $-y^2t$. where t denotes time. The equation for streamline passing through x = 1, y = 1 is

A. x^2y =1 B. x/y^2 = 1

C. xy^2 =1 D. x^2y^2 = 1

Ans. C

Sol. Given,

u = 2xyt, v = $-y^2t$

The equation of stream line in two-dimensional flow is

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

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

$$\frac{dx}{2x} + \frac{dy}{y} = 0$$

$$\frac{1}{2}\ln x + \ln y = \ln c$$

$$\ln(xy^2) = \ln c$$

xy^2 = c

since it is also passing through (1,1)

Thus,

1×1^2 = c

c = 1

thus, equation of stream line xy^2 = 1

28. The machining process that involves ablation is

A. Chemical Machining

B. Laser Beam Machining

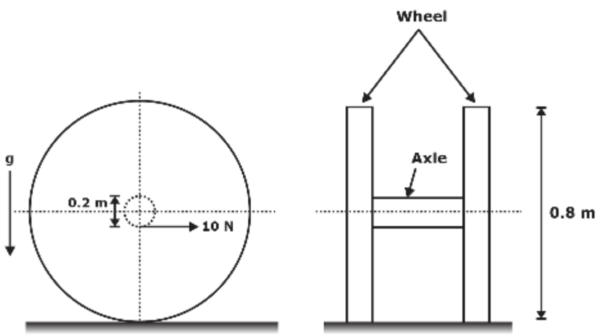
C. Electrochemical Machining

D. Abrasive Jet Machining

Ans. B

Sol. Ablation is a process in which a laser is focused on surface to remove material from the irradiation zone, thus the correct answer for the above question is Laser beam machining.

29. The wheels and axle system lying on a rough surface is shown in the figure.



Each wheel has diameter 0.8 m and mass 1 kg. Assume that the mass of the wheel is concentrated at rim and neglect the mass of the spokes. The diameter of axle is 0.2 in and its mass is 1.5 kg. Neglect the moment of inertia of the axle and assume g = 9.8 in $s^{B.}$ An effort of 10 N is applied on the axle in the horizontal direction shown at mid span of the axle. Assume that the wheels move on a horizontal surface without slip. The acceleration of the wheel axle system in horizontal direction is m/s^2 (round off to one decimal place).

Ans. 1.36

Sol.

Given,

Mass of each wheel, m= 1kg

Total mass of the wheel, = 2Kg

Diameter of wheel, D = 0.8m

Mass of axle, m_a = 1.5kg

Total mass of the system,

$2m + m_a = 2 + 1.5 = 3.5kg$

Now applying D-Almbert Principle.

Net Force = ma

$10 - 2f = 3.5a$

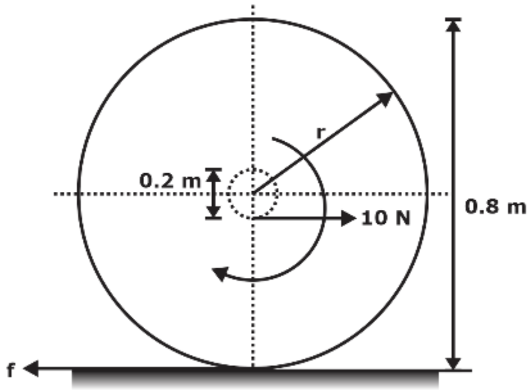
As we know,

$a = r\alpha$

$10 - 2f = 3.5 r\alpha$ (r = 0.4)

$10 - 2f = 1.4\alpha$ ……(1)

Now applying rotational equilibrium,



$\Sigma T = I\alpha$

$-10\times 0.1 + 2f \times r = 2mr^2\alpha$

$-10\times 0.1 + 2f \times 0.4 = 2\times1\times0.4^2\alpha$

$0.8f - 1 = 0.32\alpha$ ……..(2)

From equation (1) & (2)

f = 2.61N

$\alpha = 3.409 rad/s^2$

now,

$a_{CM} = r\alpha = 0.4\times3.409 = 1.363 m/s^2$

30. The mean and variance respectively of a binomial distribution for n independent trials with the probability of success as p are

A. np, np (1 – p)

B. $\sqrt{np}, \sqrt{np(1-p)}$

C. np, np

D. $\sqrt{np}, np(1-2p)$

Ans. A

Sol.

mean	Np
Variance	npq =np(1-p)
Standard deviation	$\sqrt{npq} = \sqrt{np(1-p)}$)

31. In a pure orthogonal turning by a zero rake angle single point carbide cutting tool. the shear force has been computed to be 400 N. If the cutting velocity. V_c = 100 m/min. depth of cut. t = B.0 mm. feed. s_o = 0.1 mm/revolution and chip velocity. V_f = 20 m/min. then the shear strength τ_s of the material will be _______ MPa (round off to two decimal places).

Ans.

Sol. 392.23

Given,

$\alpha = 0°$

b = d = 2mm

$f = t_1 = 0.1$ mm

V_f = 20 m/min,

V_C = 100 m/min

F_S = 400 N

$\tau_S = ?$

$$r = \frac{V_f}{V_c} = \frac{t_1}{t_2} = \frac{20}{100}$$

r = 0.2

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

$\alpha = 0$

$\tan\phi = r$

$\phi = \tan^{-1} 0.2$

$\phi = 11.31°$

$$\therefore \text{Shear strength} = \frac{\text{shear force}}{\text{sheared area}} = \frac{F_S}{As}$$

$$\tau_S = \frac{F_S}{\frac{bt_1}{\sin\phi}}$$

$$\tau_s = \frac{400}{\frac{2\times 0.1}{\sin 11.31°}} = 392.23\text{ MPa}$$

32. A PERT network has 9 activities on its critical path. The standard deviation of each activity on the critical path is 3. The standard deviation of the critical path is

A. 9
B. 3
C. 81
D. 27

Ans. A

Sol. Number of activities in critical path n = 9

Standard deviation of each activity σ_a = 3 days

Standard deviation of project

$$\sigma_p = \sqrt{\sum_{i=1}^{n} {\sigma_a}^2}$$

$$\sigma_p = \sqrt{\sum_{i=1}^{9} (3)^2}$$

$$= \sqrt{3^2+3^2+3^2+3^2+3^2+3^2+3^2+3^2+3^2}$$

$\sigma_p = 9\text{days}$

33. A shell and tube heat exchanger is used as a steam condenser. Coolant water enters the tube at 300 K at a rate of 100 kg/s. The overall heat transfer coefficient is 1500 W/m^2-K. and total heat transfer area is $400m^2$. Steam condenses at a saturation temperature of 350 K. Assume that the specific heat of coolant water is 4000 J/kg.K. The temperature of the coolant water coming out of the condenser is ________ K (round off to the nearest integer).

Ans. 338.85

Sol. Given,

m_c = 100kg/s

U = 1500W/m^2K

A = 400m^2

C_{pc} = 4000J/Kg-K

$C_{min} = C_c = m_cC_{pc} = 4\times10^5$ W/K

$$NTU = \frac{UA}{C_{min}} = \frac{1500\times 400}{4\times 10^5} = 1.5$$

Since one of the fluids is having phase change,

Thus, C = 0

$\varepsilon = 1 - e^{-NTU}$

$\varepsilon = 1 - e^{-1.5} = 0.776$

$$\varepsilon = \frac{T_{ce} - T_{ci}}{T_{hi} - T_{ci}}$$

$$0.776 = \frac{T_{ce} - 300}{350 - 300}$$

T_{ce} = 338.85K

34. Consider the following differential equation $(1+y)\frac{dy}{dx} = y$. The solution of the equation that satisfies the condition y (1) = 1 is ____________.

A. $ye^y = e^x$

B. $(1+y)e^y = 2e^x$

C. $2ye^y = e^x + e$

D. $y^2e^y = e^x$

Ans. A

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

$\frac{dy}{dx} = \frac{y}{1+y}$

$\frac{dx}{dy} = \frac{1+y}{y} = 1 + \frac{1}{y}$

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

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

$x = y + \ln y + c$

Given, y (1) = 1

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

$x = y + \ln y$

$x - y = \ln y \Rightarrow y = e^{x-y}$

$y = \frac{e^x}{e^y}$

$ye^y = e^x$

35. An object is moving with a Mach number of 0.6 in an ideal gas environment, which is at a temperature of 350 K. The gas constant is 320 J/kg. K and ratio of specific heats is 1.3. The speed of the object is ___________ m/s (round off to nearest integer).

Ans. 229

Sol. Given:

Mach Number: M =0.6

Gas constant: R = 320 J/kg

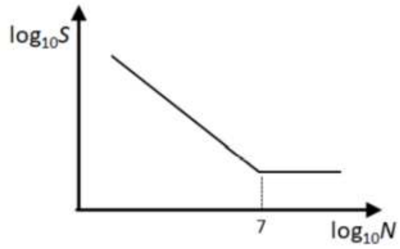
Ratio of specific heats: γ = 1.3

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

$V = 0.6\sqrt{1.3 \times 320 \times 350}$

V = 228.9 m/sec

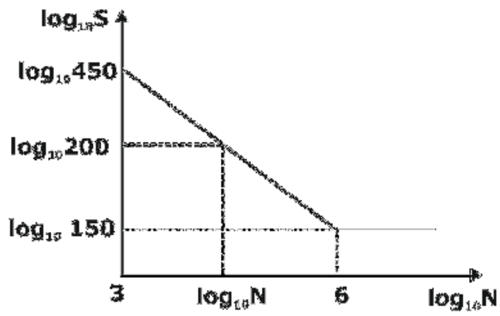
36. The figure shows the relationship between fatigue strength (S) and fatigue life (N) of a material. The fatigue strength of the material for a life of 1000 cycles is 450 MPa. while its fatigue strength for a life of 10^6 cycles is 150 MPa.



The life of a cylindrical shaft made of this material subjected to an alternating stress of 200 MPa will then be cycles (round off to the nearest integer).

Ans. 163841

Sol.



Slope of this line is same for both points:

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

$\text{Log}_{10}N = 5.214$

N = 163840.58rev.

37. A steel cubic block of side 200 mm is subjected to hydrostatic pressure of 250 N/mm^2. The elastic modulus is 2×10^5 N/mm^2 and Poisson's ratio is 0.3 for steel. The side of the block is reduced by __________mm (round off to two decimal places).

Ans. 0.10

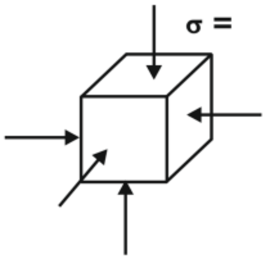
Sol. Given:

Side of cube: a = 200 mm

Young's Modulus: E = 2 × 10^5 N/mm^2 = 2× 10^{11} Pa

Pressure: P = 250 N/mm^2 = 250 MPa

Poisson's ratio: μ = 0.3



Since: E = 3K (1 – 2μ)

K = 166666.67 MPa

Volumetric strain is given by:

$$\epsilon_V = \frac{\sigma}{K} = 1.5 \times 10^{-3}$$

ΔV = 1.5 × 10^{-3} × $(200)^3$

ΔV = 12000mm^3

Change in volume:

$a'^3 = 200^3 - 12000 = mm^3$

$a'^3 = 7988000$

a' = 7988000 = 199.899

change of side = 200 - 199.899

change of side = 0.10 mm

38. Consider adiabatic flow of air through a duct. At a given point in the duct, velocity of air is 300 m/s, temperature is 330 K and pressure is 180 kPa. Assume that the air behaves as a perfect gas with constant Cp = 1.005 kJ/kg.K. The stagnation temperature at this point is ___________ (round off to two decimal places).

Ans. 374.776

Given:

In a pipe flow air flow with:

Velocity: v = 300 m/s at 330K

Pressure: P = 180 kPa.

C_p = 1.005 kJ/kg K.

Find the stagnation temperature of air.

Stagnation temperature is given by:

$$T_0 = T + \frac{V^2}{2000\ C_p}$$

$$T_o = 330 + \frac{300^2}{2000 \times 1.005}$$

T_o = 374.776K

39. If the Laplace transform of a function f (t) is given by $\frac{s+3}{(s+1)(s+2)}$, then f (0) is _____.

A. 3/2 B. 0

C. 1 D. 1/2

Ans. C

Sol. $f(0) = \lim_{s\to\infty} sF(s) = \lim_{s\to\infty} \frac{s^2+3s}{s^2+3s+2} = 1$

40. In a CNC machine tool, the function of an interpolator is to generate ____________.

A. NC code from the part drawing during post processing.

B. error signal for tool radius compensation during machining.

C. signal for the lubrication pump during machining

D. reference signal prescribing the shape of the part of the machined.

Ans. D

Sol.

- The interpolator coordinates the motion along the machine axes, which are separately driven, by providing reference positions instant by instant for the position-and velocity-control loops, to generate the required machining path.
- Typical interpolators are capable of generating linear and circular paths.

41. The thickness, width and length of a metal slab are 50 mm, 250 mm and 3600 mm, respectively. A rolling operation on this slab reduces the thickness by 10% and increase the width by 3%. The length of the rolled slab is ___________ mm (round off to one decimal place).

Ans. 3880.48

Sol. Given:

$\underset{L}{3600} \times \underset{w}{250} \times \underset{t}{40}\ mm^3$ plate

$h_f = 0.9\ h_0 = 0.9 \times 50 = 45$ mm

$b_f = 1.03 \times b_0 = 1.03 \times 250 = 257.5$ mm

Now, using Volume constancy

$b_0 \times h_0 \times L_0 = b_f \times h_f \times l_f$

$250 \times 50 \times 3600 = 257.5 \times 45 \times L_f$

$\boxed{L_f = 3880.48\ mm}$

42. The Von-mises stress at a point in a body subjected to forces is proportional to square root of _____________.

A. total strain energy per unit volume

B. dilatational strain energy per unit volume

C. distortional strain energy per unit volume

D. normal strain energy per unit volume

Ans. C

Sol.

- The Von-mises stress at a point in a body subjected to forces is proportional to square root of distortional strain energy per unit volume.

43. The torque provided by an engine is given by T(θ) = 12000 + 2500 sin(2θ) N.m. where θ is the angle turned by the crank from inner dead center. The mean speed of the engine is 200 ipm and it drives a machine that provides a constant resisting torque. If variation of the speed from the mean speed is not to exceed ± 0.5%. the minimum mass moment of inertia of the flywheel should be __________ kg.M^2 (round off to the nearest integer).

Ans. 570

Sol. Given: T = 12000 + 2500 sin2θ N-m

Mean engine speed: N = 200 rpm

$C_s = \pm 0.5\% = 0.01$

Calculate MOI of flywheel ________?

$\text{Work Done} = \int T\,d\theta = 12000\,\pi\ N-m$

$T_{mean} = 12000$ N-m

$T_{mean} = T$

Sin2θ = 0

$\theta = 0, \frac{\pi}{2}, \pi$

$$\Delta E = \int_0^{\pi/2} (12000 + 2500 \sin 2\theta - 12000) d\theta$$

$$\Delta E = 2500 \left[\frac{-\cos 2\theta}{2}\right]_0^{\pi/2}$$

$$\Delta E = -1250[\cos \pi - \cos 0^\circ]$$
$$= -1250 \times (-1-1) = 2500$$

Now:

$I\omega^2 C_s = 2500$

$$I = \frac{2500}{\left(\frac{2\pi \times 200}{60}\right)^2 \times 0.01}$$

$I = 570\ kgm^2$

44. A cast product of a particular material has dimensions 75 mm x 125 mm x 20 mm. The total solidification time for the cast product is found to be B.0 minutes as calculated using Chvorinov's rule having the index. n = B. If under tine identical casting conditions. tine cast product shape is changed to a cylinder having diameter = 50 mm and height = 50 mm. the total solidification time will be _____ minutes (round off to two decimal places).

Ans. 2.83

Sol. Given:

Material dimensions: 75 mm ×125 mm×20 mm

$C_1 \Rightarrow 75 \times 125 \times 20 \quad \rightarrow \tau_1 = 2$ min

Cylinder: $C_2 \Rightarrow D = H = 50$ mm

$\rightarrow \tau_2 =$ ________?

$$\& \ \frac{\tau_2}{\tau_1} = \left[\left(\frac{V}{A_s}\right)_2 \times \left(\frac{A_s}{V}\right)_1\right]^2$$

$$\frac{\tau_2}{\tau_1} = \left\{\frac{\frac{\pi}{4}(D)^3}{2\left(\frac{\pi}{4}D^2\right) + \pi DH} \times \frac{2[(75\times125)+(125\times20)+(20\times75)]}{75\times125\times20}\right\}^2$$

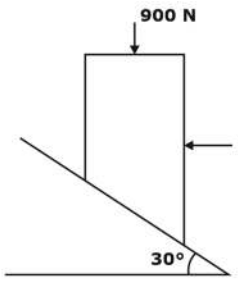
$$\frac{\tau_2}{\tau_1} = \left\{\frac{98174.77}{11780.97} \times \frac{26750}{187500}\right\}^2 = (1.1888)^2$$

$$\frac{\tau_2}{2} = 1.41 \text{min.}$$

$$\tau_2 = 1.41 \times 2$$

$$\boxed{\tau_2 = 2.82 \text{ min}}$$

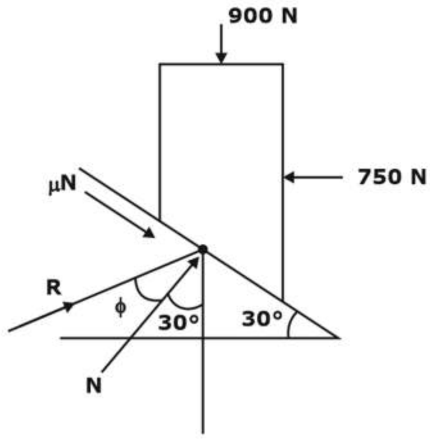
45. A block of negligible mass rests on a surface that is inclined at 30° to the horizontal plane as shown in the figure. When a vertical force of 900 N and a horizontal force of 750 N are applied, the block is just about to slide.



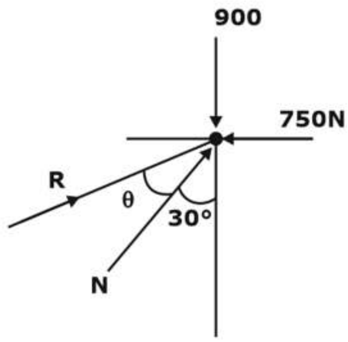
The coefficient of static friction between the block and surface is ___________ (round off to two decimal places).

Ans. 0.173

Sol. FBD of the given diagram:



By lami's theorem



$$\frac{750}{\text{Sin}(150-\phi)} = \frac{900}{\sin(120+\phi)}$$

$\Rightarrow \varphi = 9.805°$

Thus, coefficient of friction (μ) is given by:

$\mu = \tan\varphi$

$\mu = 0.173$

46. A rigid tank of volume 50 m^3 contains a pure substance as a saturated liquid vapour mixture at 400 kPa. Of the total mass of the mixture, 20% mass is liquid, and 80% mass is vapour. Properties at 400 kPa are: Saturation temperature, T_{sat} = 143.61°C; Specific volume of saturated liquid. v_f = 0.001084 m^3/kg; Specific volume of saturated vapour, v_g = 0.46242 m^3/kg. The total mass of liquid vapour mixture in the tank is _________ kg (round off to the nearest integer).

Ans. 135.079

Sol. Given,

pressure, P = 400kPa,

Volume of rigid tank, V = $50m^3$

Saturation temperature, T_{sat}

= 143.61°C

$$\text{dryness fraction}, x = \frac{m_v}{m_L + m_v} = 0.8$$

Specific volume of saturated liquid. v_f = 0.001084 m^3/kg;

Specific volume of saturated vapour, v_g = 0.46242 m^3/kg

$v = v_f + x(v_g - v_f)$

v = 0.001084 + 0.8(0.46242 – 0.001084)

v = 0.3701m^3/kg

Total mass of liquid vapour mixture in the tank is

$$m = \frac{V}{v} = \frac{50}{0.3701} = 135.079\text{kg}$$

47. A machine of mass 100 kg is subjected to an external harmonic force with a frequency of 40 rad/s. The designer decides to mount the machine on an isolator to reduce the force transmitted to the foundation. The isolator can be considered as a combination of stiffness (K) and damper (damping factor, ξ) in parallel. The designer has the following four isolators:

A. K = 640 kN/m, ξ = 0.70

B. K= 640 kN/m, ξ = 0.07

C. K = 22.5 kN/m, ξ = 0.70

D. K = 22.5 kN/m, ξ = 0.07

Arrange the isolators in the ascending order of the force transmitted to the foundation.

A. 1-3-4-2

B. 4-3-1-2

C. 1-3-2-4

D. 3-1-2-4

Ans. B

Sol. Given,

m = 100kg,

ω = 40rad/s

(i) k = 640kN/m, ζ = 0.70

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{640 \times 10^3}{100}} = 80\text{rad / s}$$

$$\frac{\omega}{\omega_n} = \frac{40}{80} = 0.5$$

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

$$\varepsilon = \frac{\sqrt{1 + (2 \times 0.7 \times 0.5)^2}}{\sqrt{\left(1 - (0.5)^2\right)^2 + (2 \times 0.7 \times 0.5)^2}}$$

$= 1.2206$

(ii) K= 640 kN/m, ξ = 0.07

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{640 \times 10^3}{100}} = 80\text{rad / s}$$

$$\frac{\omega}{\omega_n} = \frac{40}{80} = 0.5$$

$$\varepsilon = \frac{\sqrt{1 + (2 \times 0.07 \times 0.5)^2}}{\sqrt{\left(1 - (0.5)^2\right)^2 + (2 \times 0.07 \times 0.5)^2}}$$

$= 1.3308$

(iii) K = 22.5 kN/m, ξ = 0.70

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{22.5 \times 10^3}{100}} = 15\text{rad / s}$$

$$\frac{\omega}{\omega_n} = \frac{40}{15} = 2.66$$

$$\varepsilon = \frac{\sqrt{1 + (2 \times 0.7 \times 2.66)^2}}{\sqrt{\left(1 - (2.66)^2\right)^2 + (2 \times 0.7 \times 2.66)^2}}$$

$= 0.541$

(iv) K = 22.5 kN/m, ξ = 0.07

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{22.5 \times 10^3}{100}} = 15 \text{rad/s}$$

$$\frac{\omega}{\omega_n} = \frac{40}{15} = 2.66$$

$$\varepsilon = \frac{\sqrt{1 + (2 \times 0.07 \times 2.66)^2}}{\sqrt{\left(1 - (2.66)^2\right)^2 + (2 \times 0.07 \times 2.66)^2}}$$

$= 0.1753$

48. A spot welding operation performed on two pieces of steel yielding a nugget with a diameter of 5 mm and a thickness of 1 mm. The welding time was 0.1 s. The melting energy for the steel is 20 J/mm^3. Assuming the heat conversion efficiency as 10%, the power required for performing spot welding operation is ____________ kW (round off to two decimal places).

Ans. 39.269

Sol. Given:

Diameter: d = 5 mm

Thickness: h = 1 mm

volume of weld nugget:

$$V = \frac{\pi}{4} d^2 h = \frac{\pi}{4} (5)^2 \times 1$$

V = 19.63 mm^3

Heat required: $H_R = \Delta \times V$

= 19.63 × 20

H_R = 392.699 J

t = 0.1 sec

$$\therefore \frac{H_R}{\tau} = \frac{392.699}{0.1} = 3926.99 \text{ W}$$

Melting efficiency is given by:

$$\eta = \frac{H_R}{H_g} = 0.1$$

$$H_g = \frac{H_R}{0.1} = \frac{3926.99}{0.1} = 39269.9 \text{ W}$$

H_g = 39.269 kW

49. A surface grinding operation has been performed on a Cast Iron plate having dimensions 300 mm (length) × 10 mm (width) × 50 mm (height). The grinding was performed using an alumina wheel having a wheel diameter of 150 mm and wheel width of 12 mm. The grinding velocity used is 40 m/s. table speed is 5 m/min. depth of cut per pass is 50 µm and the number of grinding passes is 20. The average tangential and average normal forces for each pass are found to be 40 N and 60 N respectively. The value of the specific grinding energy under the aforesaid grinding conditions is _________ J/mm^3 (Round off to one decimal place).

Ans. 38.40

Sol. In surface griding operation performed on casting iron plate:

Plate size: 300 × 10 × 50,

Grinding wheel diameter:

D = 150 mm,

width of grinding wheel: b = 12 mm,

Cutting speed: V_C = 40 m/s,

Depth of cut: d = 50 microns,

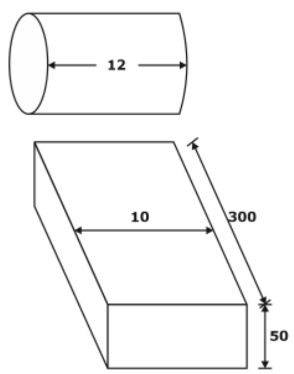
Table speed = 5 m/min

No. of passes = 20

Tangential force: $(F_t)_{avg}$ = 40 N

Normal force: $(F_N)_{avg}$ = 60 N

Specific grinding energy (J/mm^3) _______?



$V_C = 40 \text{ m/s}$

MRR = $f_t \times d \times v$

MRR =

$$10 \times 0.05 \times \frac{5000}{60} = 41.66 \text{mm}^3/\text{s}$$

Power, P = $F_c \times V$

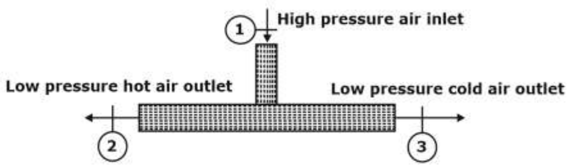
= 40 × 40 = 1600J/s

Specific grinding energy is given by:

$$U_{grinding} = \frac{\text{Power}}{\text{MRR}} = \frac{1600}{41.66}$$

$U_{grinding} = 38.4 \text{ J/mm}^3$

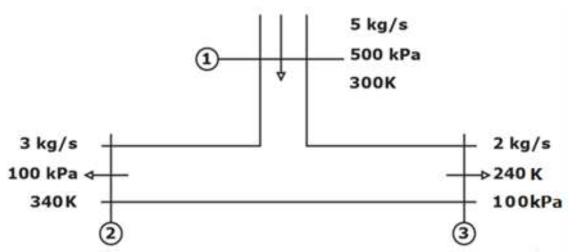
50. An adiabatic vortex tube. shown in the figure given below is supplied with 5 kg/s of air (inlet 1) at 500 kPa and 300 K. Two separate streams of air are leaving the device from outlets 2 and C. Hot air leaves the device at a rate of 3 kg/s from outlet 2 at 100 kPa and 340 K. while 2 kg/s of cold air stream is leaving the device from outlet 3 at 100 kPa and 240 K.



Consider constant specific heat of air is 1005 J kg/K and gas constant is 287 J kg/K. There is no work transfer across the boundary of this device. The rate of entropy generation is kW/K (round off to one decimal place).

Ans. 2.23

Sol. The given steady flow through an insulated pipe as shown in the figure:



For open system:

$$\frac{(ds)_{cv}}{dt} = \frac{d\dot{Q}}{T} + \delta\dot{S}_{gen} + \dot{m}_i\dot{s}_i - \dot{m}_e\dot{s}_e$$

For steady how: $\frac{(ds)_{cv}}{dt} = 0$

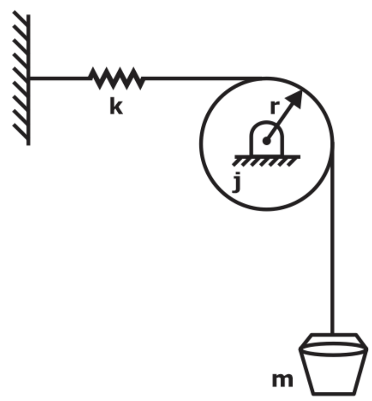
For insulated: $\frac{d\dot{Q}}{T} = 0$

$$\delta\dot{S}_{gen} = 3\left[C_p \ln\left(\frac{340}{300}\right) - R\ln\left(\frac{100}{500}\right)\right]$$

$$+2\left[C_p \ln\left(\frac{240}{300}\right) - R\ln\left(\frac{100}{500}\right)\right]$$

$\delta\dot{S}_{gen}$ = 1.76 + 0.47 = 2.23 kJ/K

51. Consider the system shown in the figure. A rope goes over a pulley. A mass, m, is hanging from the rope. A spring of stiffness, k, is attached at one end of the rope. Assume rope is inextensible, massless and there is no slip between pulley and rope.



The pulley radius is r and its mass moment of inertia is J. Assume the mas is vibrating harmonically about is equilibrium position. The natural frequency of the system is ___________.

A. $\sqrt{\frac{k}{m}}$

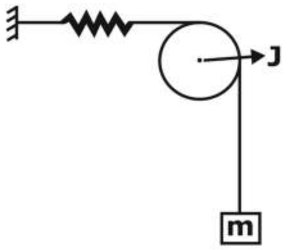
B. $\sqrt{\frac{kr^2}{J}}$

C. $\sqrt{\frac{kr^2}{J - mr^2}}$

D. $\sqrt{\frac{kr^2}{J + mr^2}}$

Ans. D

Sol.



Kinetic energy is given by:

$$KE = \frac{1}{2} m \dot{x}^2 + \frac{1}{2} J \dot{\theta}^2 = \frac{1}{2}[J + mr^2]\dot{\theta}^2$$

Potential energy is given by:

$$PE = \frac{1}{2} kx^2 = \frac{1}{2} k r^2 \ \theta^2$$

Now, $\frac{d}{d\theta}(TE) = 0$

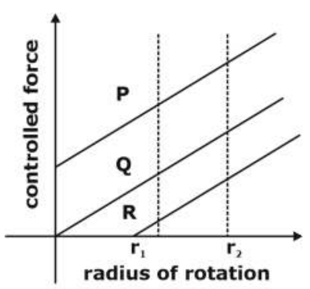
$$\frac{d}{d\theta}\left\{\frac{1}{2}[J + mr^2]\dot{\theta}^2 + \frac{1}{2} k r^2 \ \theta^2\right\} = 0$$

$$\frac{1}{2}(J + mr^2)2\,\dot{\theta}\,\ddot{\theta} + \frac{1}{2} kr^2\ 2\,\theta\,\dot{\theta} = 0$$

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

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

52. The Controlling force curves P, Q and R for a spring-controlled governor are shown in the figure. Where r_1 and r_2 are any two radii of rotation.



The Characteristics shown by the curves are ____________.

A. P-Unstable, Q-Isochronous, R-stable

B. P-Unstable, Q-stable, R- Isochronous

C. P-Stable, Q- Unstable, R- Isochronous

D. P-Stable, Q- Isochronous, R-Unstable

Ans. A

Governing equation for spring-controlled governor

F = ar +b   For stable governor, thus R will be stable

F = ar - b   For unstable governor, thus P will be unstable

F = ar   For isochronous governor, thus Q will be isochronous

53. The cast iron which possesses all the carbon in the combined form as cementite is known as ____________.

A. Gray Cast Iron

B. White Cast Iron

C. Malleable Cast Iron

D. spheroidal Cast Iron

Ans. B

Sol.

- In white cast iron the carbon precipitates out of the melt as the metastable phase cementite i.e., Fe_3C rather than graphite.
- In malleable – carbon is agglomerates into small roughly spherical aggregates of graphite.

54. Value of $\int_4^{5.2} \ln x \, dx$ using Simpson's one third rule with interval size 0.3 is ___________.

A. 1.60

B. 1.06

C. 1.83

D. 1.51

Ans. C

Sol. Given:

$$f(x) = \int_{4}^{5.2} \ln x \, dx$$

h = 0.3

f (4) = ln 4 a

f (4.3) = ln 4.3 x_1

f (4.6) = ln (4.6) x_2

f (4.9) = ln (4.9) x_3

f (5.2) = ln (5.2) b

S_0 = f (4) + f (5.2) = ln 4 ln + (5.2) = ln (20.8)

= 3.03

S_1 = f (4.3) + f (4.9) = ln

(4.3 × 4.9) = 3.05

S_2 = f (4.6) = ln (4.6) = 1.53

$$I = \frac{h}{3}\left[S_0 + 4S_1 + 2S_2\right] = 1.829$$

55. The size distribution of the powder particles used in Powder Metallurgy Process can be determined by ____________.

A. Laser scattering

B. Laser penetration

C. Laser absorption

D. Laser reflection

Ans. A

- Particle size analysis of metal powders has been performed using various techniques through the years including microscope, sieves, aerodynamic time of flight, and laser diffraction.

The most popular technique for measuring the size distribution of metal powders is now **laser diffraction**, typically measured in its natural state as a dry powder. Laser diffraction **uses Mie theory of light scattering to calculate the particle size distribution**, assuming a volume equivalent sphere model.

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