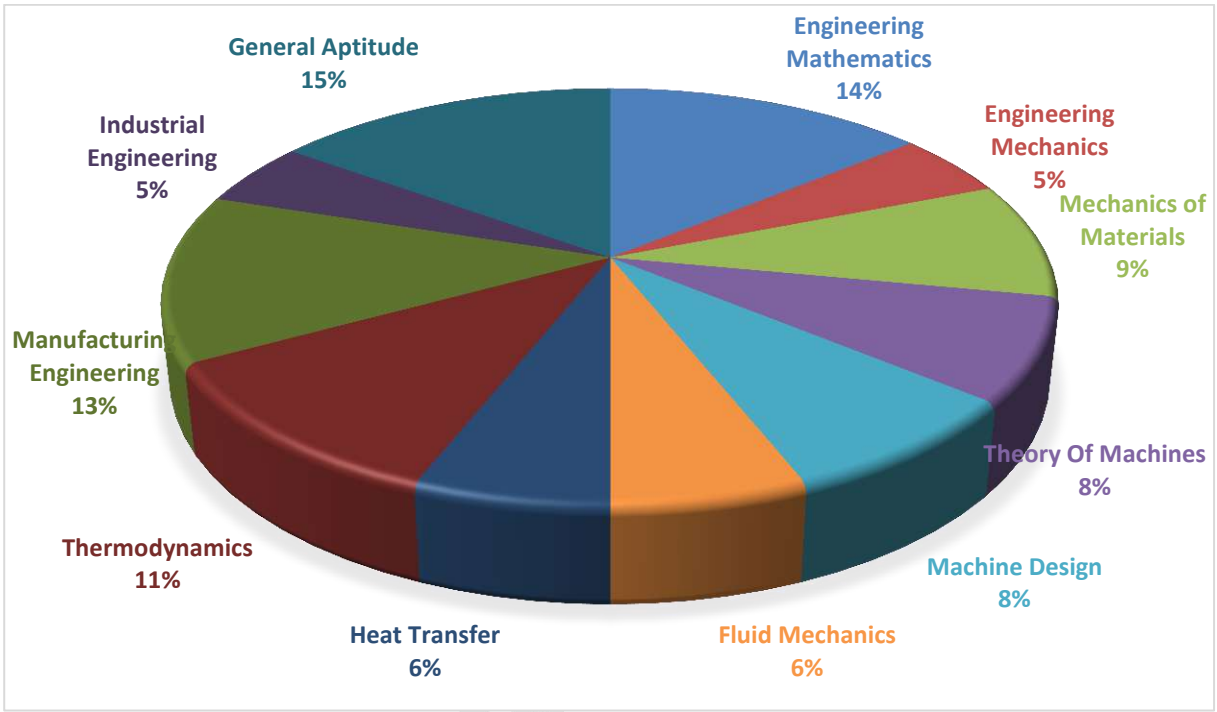
ANALYSIS OF GATE 2019

Mechanical Engineering



ME ANALYSIS-2019_2-Feb_Morning

SUBJECT	No. of Ques.	Topics Asked in Paper(Memory Based)	Level of Ques.	Total Marks
Engineering Mathematics	1 Marks: 6 2 Marks: 4	Matrix, Numerical Method, Differential Equation, Probability, Calculus	Easy	14
Engineering Mechanics	1 Marks: 1 2 Marks: 2	Friction, Truss	Medium	5
Mechanics of Materials	1 Marks: 3 2 Marks: 3	Stress Analysis, Testing of Materials	Easy	9
Theory Of Machines	1 Marks: 2 2 Marks: 3	Vibration, Gyroscope, Mechanism, Cam	Medium	8
Machine Design	1 Marks: 2 2 Marks: 3	Brake, Gear, TOF	Easy	8
Fluid Mechanics	1 Marks: 2 2 Marks: 2	Kinematic Analysis, Euler's Equation, Fluid kinematics	Easy	6
Heat Transfer	1 Marks: 2 2 Marks: 2	Shape factor, Thermal conductivity	Medium	6
Thermodynamics	1 Marks: 3 2 Marks: 4	Ist Law, Refrigeration, SFEE	Medium	11
Manufacturing Engineering	1 Marks: 3 2 Marks: 5	Casting, Welding, Machining	Tough	13
Industrial Engineering	1 Marks: 1 2 Marks: 2	Pert CPM, Assignment, Forecasting	Medium	5
General Aptitude	1 Marks: 5 2 Marks: 5	Blood relationship, Percentage, Equation, Clocks	Medium	15
Total	**65**			**100**
Faculty Feedback	Easy Questions Covering a wider range of topics rather than going too deep in Important topics.			

GATE 2019 Examination

Mechanical Engineering

Test Date: 2-FEB-2019

Test Time: 9.30 AM to 12:30 PM

Subject Name: Mechanical Engineering

General Aptitude

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

1. A worker noticed that the hour hand on the factory clock had moved by 225 degree during her stay at the factory. For how long did she stay in the factory?
   (A) 4 hours and 15 mins
   (B) 3.75 hours
   (C) 8.5 hours
   (D) 7.5 hours
   [Ans. D]
   The hour hand of a clock moves $\frac{360}{12} = 30°$ per hour.
   So, as the hour hand had moved 225°, means the women works in the factory for $225/30 = 7.5$ hours

2. The minister avoided any mention of the issue of women's reservation in the private sector. He was accused of _____ the issue
   (A) Belting
   (B) Skirting
   (C) Tying
   (D) collaring
   [Ans. B]
   Skirting means attempt to ignore
   Collaring means to seize someone
   Belting means beat or strike someone, especially by belt, as a punishment
   Tying means restrict or limit someone at any place or situation.

3. The sum and product of two integers are 26 and 165 respectively. The difference between these two integers is _____
   (A) 3
   (B) 2
   (C) 4
   (D) 6

[Ans. C]

Given,

$(a + b) = 26$

$(a * b) = 165$

$\because (a + b)^2 = (a - b)^2 + 4ab$

$(26)^2 = (a - b)^2 + (4 * 165)$

$\Rightarrow (a - b)^2 = 676 - 660$

$\Rightarrow (a - b)^2 = 16$

$\therefore (a - b) = 4$

4. John Thomas, an_____ writer passed away in 2018

(A) Imminent
(B) Dominant
(C) Eminent
(D) prominent

[Ans. C]

Prominent means: Important, famous, well-known
Imminent means: about to happen
Dominant means: having power and influence others
And Eminent means: well qualified
Since, the question talks about a writer, therefore 'eminent' will be the suitable word.

5. _____ I permitted him to leave I wouldn't have had any problem with him being absent, _____ I?

(A) Have, would
(B) Had, wouldn't
(C) Had, would
(D) Have, wouldn't

[Ans. C]

Had, I permitted him to leave, I wouldn't have had any problem past perfect conditional sentence pattern.

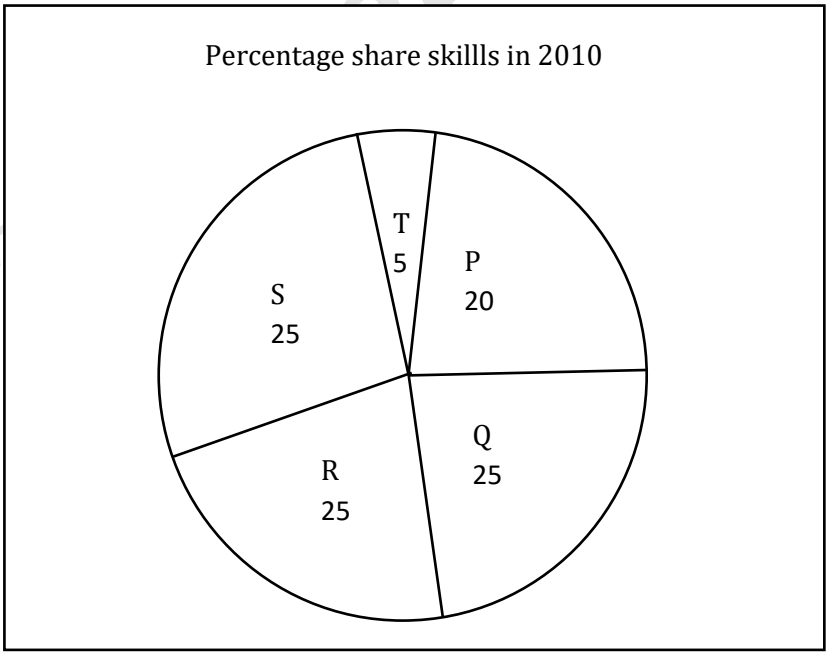
$\underbrace{\text{Had} + V_3\text{form}}_{\text{If clause}}, \underbrace{\text{would have} + V_3\text{form}}_{\text{main clause}}$

Negative statement requires affirmative question tag so would I?

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

6. Conge was name by Europeans. Congo's dictator Mobuto later changed the name of the country and the river to Zaire with the objective of Africanising names of persons and spaces. However, the name Zaire was a Portugese alteration of Nzadi o Nzere, a local African term meaning 'River that swallows Rivers'. Zaire was the Portugese name for the Congo river in the 16th and 17th centuries.
Which one of the following statements can be inferred from the paragraph above?
(A) Mobuto was not entirely successful in Africanising the name of his country
(B) The term Nzadi o Nzere was of Portugese origin
(C) Mobuto's desire to Africanise names was prevented by the Portugese
(D) As a dictator Mobuto ordered the Portugese to alter the name of the river to Zaire
[Ans. A]
As the paragraph states, dictator Mobuto wanted to Africanise the name of Congo but could not succeed as the new name given to the country was Portuguese alteration of some other term.

7. A firm hires employees at five different skill levels P, Q, R, S, T. The shares of employment at these skill levels of total employment in 2010 is given in the pie chart as shown. There were a total of 600 employees in 2010 and the total employment increased by 15% from 2010 to 2016. The total employment as skill levels P, Q and R remained unchanged during this period. If the employment at skill level S increased by 40% from 2010 to 2016, how many employees were there at skill level T in 2016?



(A) 72

(B) 30
(C) 60
(D) 35

[Ans. C]

	2010	2015
P	120	120
Q	150	150
R	150	150
S	150	210
T	30	60
	600	690

630

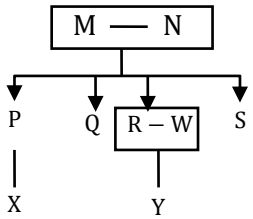
8. Under a certain legal system, prisoners are allowed to make one statement. If their statement turns out to be true then they are hanged. If the statement turns out to be false then they are shot. One prisoner made a statement and the judge had no option but to set him free. Which one of the following could be that statement?
(A) I committed the crime
(B) You committed the crime
(C) I will be shot
(D) I did not commit the crime

[Ans. C]

Remaining three options would lead to the prisoner being hanged or shot. This answer choice creates two contradictory situations.

9. M and N had four children P, Q, R and S. of them, only P and R were married. They had children X and Y respectively. If Y is a legitimate child of W, which one of the following statements is necessarily FALSE?
(A) W is the wife of R
(B) R is the father of Y
(C) M is the grandmother of Y
(D) W is the wife of P

[Ans. D]



'W' can be husband or wife of R. so, R can be father or mother of Y. Since, gender of M and N are also not defined. So, M can be grandmother or grandfather of Y.
But W **can't** be wife of P.

10. A person divided an amount of Rs. 100.000 into two parts and invested in two different schemes. In one he got 10% profit and in the other he got 12%. If the profit percentages are interchanged with these investments he would have got Rs. 120 less. Find the ratio between his investments in the two schemes.

(A) 11:14
(B) 37:63
(C) 9:16
(D) 47:53

[Ans. D]

Let the amount be distributed as 'x' and 'A − x' where 'A' is Rs.1,00,000

Case-I:

$(10\% \text{ of } x)+(12\% \text{ of } (A-x))= 12\% \text{ of } A - 2\% \text{ of } x$ _____①

Case-II:

$(12\% \text{ of } x)+(10\% \text{ of } (A-x))=10\% \text{ of } A + 2\% \text{ of } x$ _____②

According to the condition:

$① - ② = 120$

$\Rightarrow (2\% \text{ of } A - 4\% \text{ of } x) = 120$

$\Rightarrow (2000 - 4\% \text{ of } x) = 120 \quad \because A = 1{,}00{,}000 \text{ and } (2\% \text{ of } 1{,}00{,}000) = 2000$

$\Rightarrow (4\% \text{ of } x) = 2000 - 120 = 1880$

$\Rightarrow x = \dfrac{1880 \times 100}{4} = 47{,}000$

$A - x = 53{,}000$

$\therefore \text{Ratio} = 47:53$

Technical

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

1. During a high cycle fatigue test, a metallic specimen is subjected to cyclic loading with a mean stress of +140 MPa, and a minimum stress of -70 MPa. The R-ratio (minimum stress to maximum stress) for this cyclic loading is _____ (round off to one decimal place)

[Ans. *]Range -0.2 to -0.2

2. The table presents the demand of a product. By simple three-months moving average method, the demand-forecast of the product for the month of September is

Month	Demand
January	450
February	440
March	460
April	510
May	520
June	495

July	475
August	560

(A) 490
(B) 510
(C) 536.67
(D) 530

[Ans. B]

Demand for the month of September

$$(D_{sept}) = \frac{495 + 475 + 560}{3}$$

$= 510$

3. Consider the matrix

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

The number of distinct eigenvalues of P is

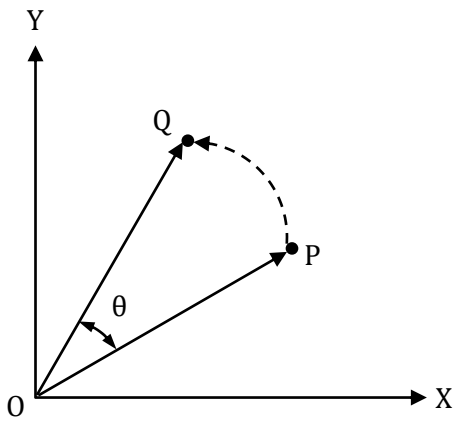
(A) 2
(B) 1
(C) 0
(D) 3

[Ans. B]

$$\mathbf{A} = \begin{matrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{matrix}$$

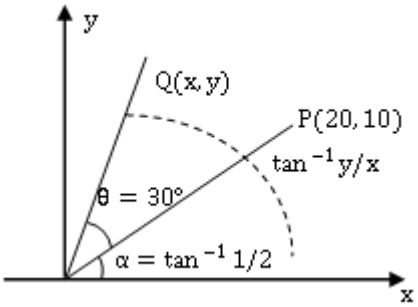
Since given matrix is U.T.M. So, diagonal elements are the eigen values. Hence, $\lambda = 1, 1, 1$. So matrix has only one distinct eigen value i.e.

4. The position vector $\overrightarrow{OP}$ of point P (20, 10) is rotated anti-clockwise in X-Y plane by an angle $\theta = 30^0$ such that point P occupies position Q, as shown in the figure. The coordinates (x, y) of Q are



(A) (13.40, 22.32)
(B) (18.66, 12.32)
(C) (12.32,18.66)
(D) (22.32, 8.26)

[Ans. C]



$\theta + \alpha = 30° + \tan^{-n}(0.5)$
$= 56.56$
(12.32, 18. 66)

5. A slender rod of length L, diameter d (L ≫ d) and thermal conductivity K_1 is joined with another rod of identical dimensions, but of thermal conductivity k_2, to form a composite cylindrical rod of length 2L. The heat transfer in radial direction and contact resistance are negligible. The effective thermal conductivity of the composite rod is

(A) $\sqrt{k_1 k_2}$

(B) $k_1 + k_2$

(C) $\dfrac{k_1 k_2}{k_1 + k_2}$

(D) $\dfrac{2k_1 k_2}{k_1 + k_2}$

[Ans. D]

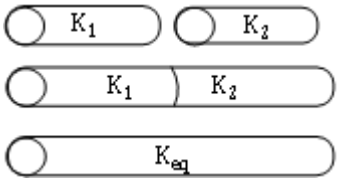
For longitudinal heat condition

$R_T = R_1 + R_2$ [Series]

$$\frac{L_1}{k_1 A_1} + \frac{L_2}{k_2 A_2}$$

$$= \frac{L}{A}\left[\frac{1}{k_1} + \frac{1}{k_2}\right]$$

$$R_{eq} = \frac{2L}{kA}$$



$$\frac{2L}{kA}=\frac{L}{A}\left[\frac{1}{k_1}+\frac{1}{k_2}\right]\Rightarrow k=\frac{2}{\frac{1}{k_1}+\frac{1}{k_2}}=\frac{2k_1k_2}{k_1+k_2}$$

6. Water flows through a pipe with a velocity given by $\vec{V}=\left(\frac{4}{t}+x+y\right)\hat{j}$ m/s, where $\hat{j}$ is the unit vector in the y direction. $t(>0)$ is in seconds, and x and y are in meters. The magnitude of total acceleration at the point $(x, y)=(1,1)$ at $t=2$ s is_____m/s^2.

[Ans. *]Range 3 to 3

$$\vec{V}=\left(\frac{4}{t}+x+y\right)\hat{J}$$

$$a=\sqrt{a_x^2+a_y^2+a_z^2}$$

$$a=a_z$$

$$a_y=V\frac{\partial v}{\partial y}+\frac{\partial v}{\partial t}=a$$

$$\text{At } x=1;\ y=1;\ t=2\ a=3\ m/s^2$$

7. A cylindrical rod of diameter 10 mm and length 1.0 m is fixed at one end. The other end is twisted by an angel of 10^0 by applying a torque. If the maximum shear strain in the rod is $p\times10^{-3}$, then p is equal to _____ (round off to two decimal places)

[Ans. *]Range 0.80 to 0.90

Using torsion equation

$$\frac{\tau}{R}=\frac{G\theta}{L}$$

$$\text{Shear strain } \gamma=\frac{\tau}{G}=\frac{R\theta}{L}$$

$$=\frac{(5\times10^{-3})}{1}\times\left(\frac{1071}{180}\right)$$

$$\gamma=0.87266\times10^{-3}$$

$$\Rightarrow P=0.87266$$

8. A spur gear with 20^0 full depth teeth is transmitting 20 kW at 200 rad/s. the pitch circle diameter of the gear is 100mm. the magnitude of the force applied on the gear in the radial direction is

(A) 1.39 kN
(B) 0.73 kN
(C) 2.78 kN
(D) 0.36 kN

[Ans. B]

$\emptyset = 20°$

P = 20 kW

$\omega = 200$ rad/s

D = 100 mm

We know that, power, $P = T \times \omega$

$20 \times 103 = T \times 200$

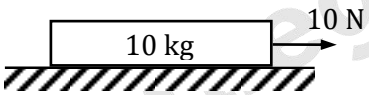
T = 100 N-m

We know that, $T = Ft \times r$

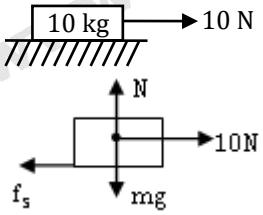
$$F_t = \frac{2T}{D} = 2 \times \frac{100}{100 \times 10^{-3}} = 2 \text{ kN}$$

Radial force, $Fr = Ft(\tan \varphi) = 2 \times \tan 20° = 0.72794 \text{ kN} = 0.728 \text{ kN}$
$= 0.73$ kN

9. A block of mass 10 kg rests on a horizontal floor. The acceleration due to gravity is 9.81 m/s^2. The coefficient of static friction between the floor and the block is 0.2. A horizontal force of 10 N is applied on the block as shown in the figure. The magnitude of force of friction (in N) on the block is_____



[Ans. *]Range 10 to 10



$\varepsilon F_y = 0$

$N - mg = 0$

N=mg

Block is at rest , so static friction will act on it

Maximum value of static friction

$(f_s)_{max} = \mu N = \mu mg$

$= 2 \times 10 \times 9.81$

$= 19.62$ N

But block is at rest and applied force is 10N so friction force acting=applied force

$= 10$N

10. During a non-flow thermodynamic process (1-2) executed by a perfect gas, the heat interaction is equal to the work interaction ($Q_{1-2} = W_{1-2}$) when the process is

(A) Adiabatic

(B) Polytropic

(C) Isothermal

(D) Isentropic

[Ans. C]

For non-flow process, 1^{st} law of thermodynamics is $Q = du + w$

For ideal gas $Q = C_v\, dt + w$

For $Q = w$

dt must be zero i.e., the process is isothermal

11. Evaluation of $\int_2^4 x^3 dx$ using a 2-equal-segment trapezoidal rule gives a value of _____

[Ans. *]Range 63 to 63

$$\int_2^4 x^3\ dx$$

Trapezoidal rule

n=z

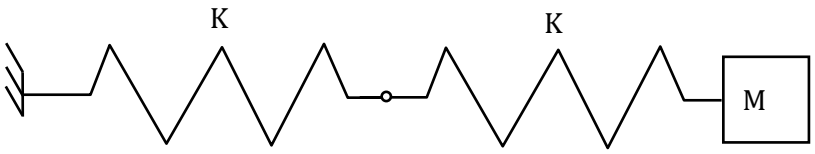
$$h = \frac{b-a}{n} = \frac{2}{2} = 1$$

x	2	3	4
y	8	27	64

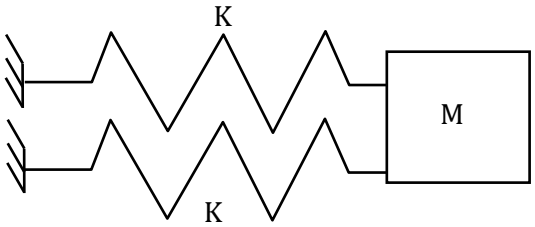
$$\int_2^4 x^3\ dx = \frac{1}{2}\left(72 + 2(27)\right)$$

$= 63$

12. The natural frequencies corresponding to the spring-mass systems I and II are ω_I and ω_{II}, respectively. The ratio $\frac{\omega_I}{\omega_{II}}$ is



SYSTEM I



SYSTEM II

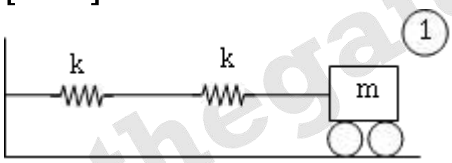
(A) $\frac{1}{4}$

(B) $\frac{1}{2}$

(C) 2

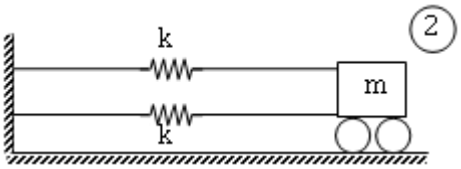
(D) 4

[Ans. B]



$$\frac{1}{(k_{eq})_1} = \frac{1}{k} + \frac{1}{k} \Rightarrow (k_{eq})_1 = \frac{k}{2}$$

$$\omega_{n1} = \sqrt{\frac{k}{2m}} \cdots (1)$$



$$(k_{eq})_2 = k + k \Rightarrow (k_{eq})_2 = 2k$$

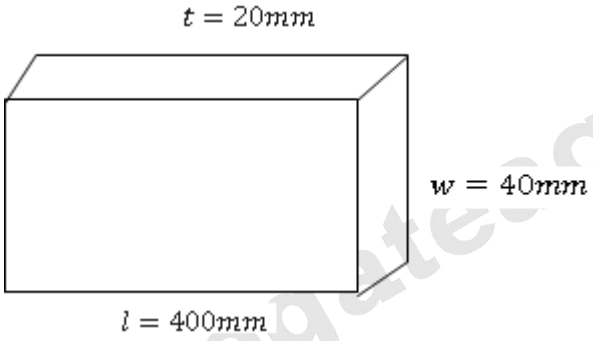
$$\omega_{n_2} = \sqrt{\frac{2k}{m}} \cdots (2)$$

Equation $\frac{①}{②}\ \frac{\omega_{n1}}{\omega_{n2}} = \sqrt{\frac{\frac{k}{2m}}{\frac{2k}{m}}} = \frac{1}{2} = 0.5$

13. The length, width and thickness of a steel sample are 400 mm, 40 mm and 20mm, respectively. Its thickness needs to be uniformly reduced by 2 mm in a single pass by using horizontal slab milling. The milling cutter (diameter: 100 mm, width: 50 mm) has 20 teeth and rotates at 1200rpm. The feed per tooth is 0.05mm. The feed direction is along the length of the sample. If the over-travel distance is the same as the approach distance, the approach distance and time taken to complete the required machining task are

(A) 21 mm, 39.4 s
(B) 21mm, 28.9 s
(C) 14mm, 18.4 s
(D) 14mm, 21.4 s

[Ans. D]



Cutter diameter, D = 100 mm
Cutter width = 50 mm that means single pass is sufficient.
Number of teeth, z = 20, Depth of cut, d = 2 mm
Rotational speed, N = 1200 rpm, f = 0.05 mm per tooth

Approach distance, $A = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - d\right)^2} = \sqrt{d(D-d)}$

$= \sqrt{2(100-2)\text{mm}} = 14$ mm

Time for one pass in slab or slot milling

$= \frac{L+A}{fzN}$ for rough milling $= \frac{L+2A}{fzN}$ for finish milling

As length of approach and over travel are same

$= \frac{L+A+A}{fzN} = \frac{400+14+14}{0.05\times 20\times 1200}$ min $= 21.4$ s

14. A solid cube of side 1 m is kept at a room temperature of 32 °C. The coefficient of linear thermal expansion of the cube material is 1×10^{-5} / °C and the bulk modulus is 200 GPa. If the cube is constrained all around and heated uniformly to 42 °C, then the magnitude of volumetric (mean) stress (in MPa) induced due to heating is _____

[Ans. *]Range 60 to 60

Strain in any direction (ie, x, y, and z) will be zero

$\epsilon_x = (\epsilon)_{thermal} + (\epsilon)_{axial}$

$0 + (\alpha \Delta T) + \frac{\sigma_x}{E} - \frac{\mu}{E}(\sigma_y + \sigma_z)$

(where $\sigma_x = \sigma_y = \sigma_x = \sigma_z = \sigma$

$\frac{\sigma}{E}(1 - 2\mu) = \alpha . \Delta T$

$\sigma = \frac{-\alpha . \Delta T . E}{(1 - 2\mu)}$

use $E = 3k\,(1 - 2\mu)$

$\sigma = -3k\,.\,\alpha . \Delta T$

$= -3 \times\times 200 \times 10^3 \times 10^{-5} \times (42 - 32)$MPa

$\sigma = -60$ MPa

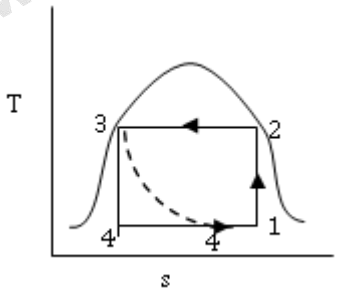
ie 60MPa (compressine)

Magnitude of stress(volumetric)=60MPa

15. Consider an ideal vapor compression refrigeration cycle. If the throttling process is replaced by an isentropic expansion process, keeping all the other processes unchanged, which one of the following statements is true for the modified cycle?

(A) Coefficient of performance is higher than that of the original cycle.
(B) Coefficient of performance is lower than that of the original cycle.
(C) Refrigeration effect is lower than that of the original cycle.
(D) Coefficient of performance is the same as that of the original cycle.

[Ans. A]



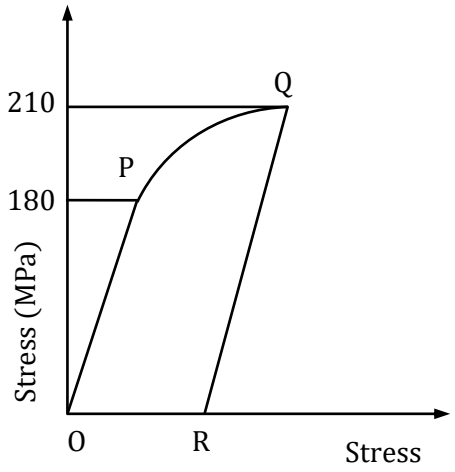
Throttling process =3 to 8 isentropic (Reversible adiabatic) expansion =3 to 4
In case of adiabatic expansion refrigeration effect=4 to 1
In case of adiabatic expansion refrigeration effect=4 to 1
Cleary RE adiabatic > RE Throttling
Work to compressor is same form both the cycle (1 to 2)

We know COP $= \frac{RE}{w}$ So COP adiabatic $>$ CO $P_{Throttling}$

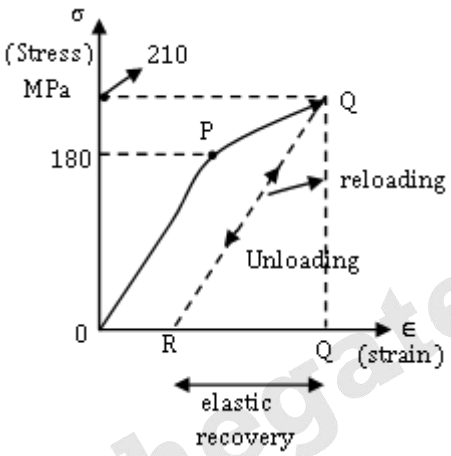
16. In a casting process, a vertical channel through which molten metal flows downward from pouring basin to runner for reaching the mold cavity is called
(A) Blister
(B) Sprue
(C) Pin hole
(D) Riser
[Ans. B]

17. for a hydrodynamically and thermally fully developed laminar flow through a circular pipe of constant cross-section, the Nusselt number at constant wall heat flux (Nu_q) and that at constant wall temperature (Nu_T) are related as
(A) $Nu_q > Nu_T$
(B) $Nu_q < Nu_T$
(C) $Nu_q = Nu_T$
(D) $Nu_q = (Nu_T)^2$
[Ans. A]
For fully developed laminar flow through pipes, Nusselt number value corresponding to uniform heat flux is 4.36. Nusselt number value corresponding to uniform wall temperature is 3.66.
Hence, $Nu_q > Nu_t$

18. Consider the stress-strain curve for an ideal elastic-plastic strain hardening metal as shown in the figure. The metal was loaded in uniaxial tension starting from O. upon loading, the stress-strain curve passes through initial yield point at P, and then strain hardens to point Q, where the loading was stopped. From point Q, the specimen was unloaded to point R, where the stress is zero. If the same specimen is reloaded in tension from point R, the value of stress at which the material yields again is _____ MPa.

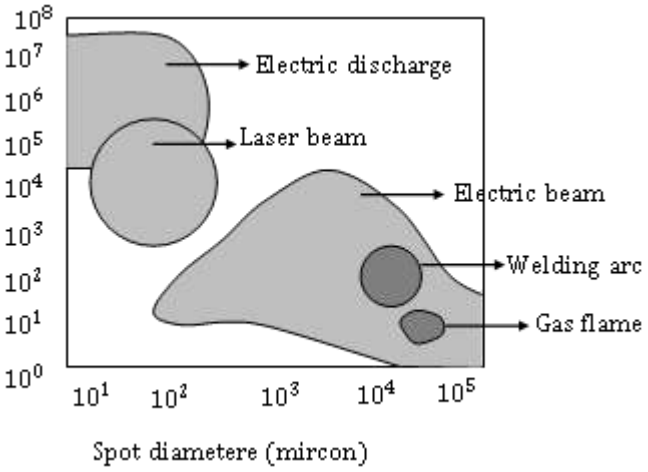


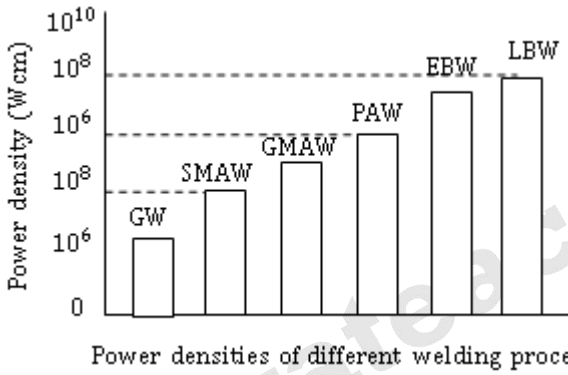
[Ans. *]Range 210 to 210



$\in_{RQ}$ is the strain corresponding to elastic recovery after unloading
During elastic recovery QR will be parallel to line OP
When the same specimen is reloaded again in tension from the same situation (R) , it will follow the same path of unloading
Therefore $\sigma_{yield} = \sigma_Q = 210$ MPa ∠because
The specimen can store maximum elastic energy up to point Q

19. Which one of the following welding methods provides the highest heat flux (W/mm^2)?
(A) Tungsten inert gas welding
(B) Plasma are welding
(C) Oxy-acetylene gas welding
(D) Laser beam welding
[Ans. D]
In laser beam welding heat flux is highest upto 1 MW/mm^2





Power densities of different welding process

Sr. No	Welding Process	Heat Density $\left(\frac{W}{cm^2}\right)$	Temperature(°C)
1	Gas welding	$10^2 - 10^3$	2500-3500
2	Shielded meta arc welding	10^4	>6000
3	Gas metal arc welding	10^5	8000-10000
4	Plasma arc welding	10^6	15000-30000
5	Electron beam welding	$10^7 - 10^8$	20000-30000
6	Laser Beam welding	$> 10^8$	>30000

20. As per common design practice, the three types of hydraulic turbines, in descending order of flow rate, are
(A) Kaplan, Francis, Pelton
(B) Pelton, Francis, Kaplan
(C) Pelton, Kaplan, Francis
(D) Francis, Kaplan, Pelton

[Ans. A]

Since the pelton turbines are impulse turbine they need high velocity of fluid to work, hence to get high velocity , high head is required $(V\alpha\sqrt{h})$, Francis works on medium head

and kaplan turbine can exploit low heads since Power= energy i.e Power αQH, The turbines with high head, requires low discharge hence the order of discharge is kaplan> Francis> Pelton

21. For the equation $\frac{dy}{dx} + 7x^2y = 0$, if $y(0) = 3/7$, then the value of y (1) is

(A) $\frac{3}{7}e^{-3/7}$

(B) $\frac{7}{3}e^{-7/3}$

(C) $\frac{3}{7}e^{-7/3}$

(D) $\frac{7}{3}e^{-3/7}$

[Ans. C]

$$\frac{dy}{dx} + 7x^2y = 0$$

$$y(0) = \frac{3}{7}$$

$$y(1) = ?$$

$$\frac{dy}{dx} = -7x^2y$$

$$\frac{dy}{y} = -7x^2\,dx$$

$$\int \frac{dy}{y} = -\int 7x^2\,dx$$

$$\ln(y) = -\frac{7x^3}{3} + c$$

$$y = ke^{-\frac{7x^3}{3}}$$

$$y(0) = \frac{3}{7} = k(1)$$

$$k = \frac{3}{7}$$

$$y(1) = \frac{3}{7}e^{-7/3}$$

22. Air of mass 1 kg, initially at 300 K and 10 bar, is allowed to expand isothermally till it reaches a pressure of 1 bar. Assuming air as an ideal gas with gas constant of 0.287 kJ/kg.K, the change in entropy of air (in kJ/kg. K, round off to two decimal places) is _____

[Ans. *]Range 0.64 to 0.68

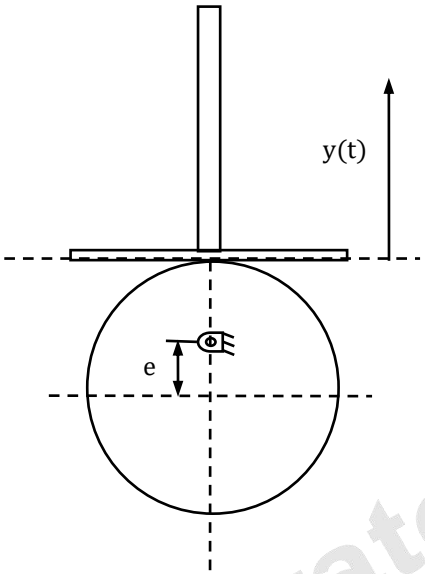
We know $\Delta s = C_P \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$

Since the compression is isothermal $T_2 = T_1$

So $\Delta s = -R \ln \frac{P_2}{P_1} = -0.287 \times \ln \frac{10}{1}$

$= -0.6608\ \text{kJ/kg k}$

23. A flat-faced follower is driven using a circular eccentric cam rotating at a constant angular velocity ω. At time t = 0, the vertical position of the follower is y(0) = 0, and the system is in the configuration shown below.



The vertical position of the follower face, y (t) is given by

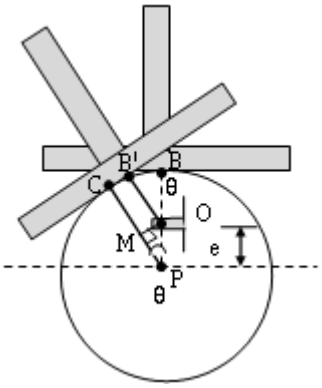
(A) $e(1 + \cos 2\omega t)$

(B) $e \sin 2\omega t$

(C) $e(1 - \cos \omega t)$

(D) $e \sin \omega t$

[Ans. C]

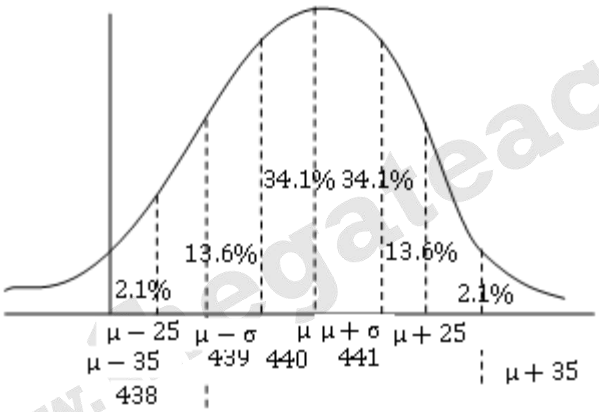


Displacement of follower

y = OB′ − OB (OB′will be parallel to PC)

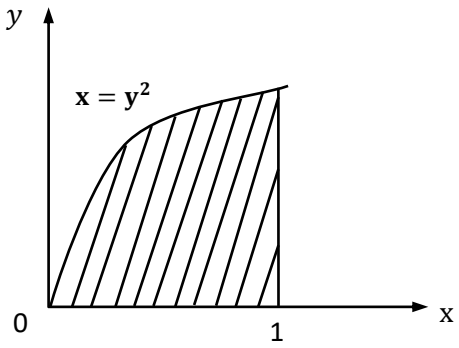
= CM – OB
= (PC – PM) – OB
(OB′ = CM)
= R − e cos θ − (R − e) = R − e cos θ − R + e
= e(1 − cos θ) (In time(t) θ = ωt)
= e(1 − cos θt)

24. The length of a large stock of titanium rods follow a normal distribution with a mean (μ) of 440 mm and a standard deviation (σ) of 1mm. what is the percentage of rod whose lengths lie between 438 mm and 441mm?
(A) 81.85%
(B) 68.4%
(C) 86.64%
(D) 99.75%
[Ans. A]
μ = 440mm
σ = 1mm



438mm − 441mm
13.6 + 34.1 + 34.1
13.6 + 68.2
81.8%

25. A parabola $x = y^2$ with $0 \leq x \leq 1$ is shown in the figure. The volume of the solid of rotation obtained by rotating the shaded area by 360 ° around the x-axis is



(A) 2π
(B) $\frac{\pi}{2}$
(C) π
(D) $\frac{\pi}{4}$

[Ans. B]

$$\int_0^1 \pi (y)^3 \, dx$$

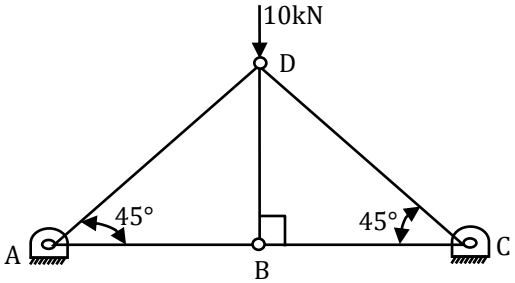
$$y^2 = x$$

$$\int_0^1 \pi x \, dx$$

$$\pi \left(\frac{x^2}{2}\right)_0^1 = \frac{\pi}{2}$$

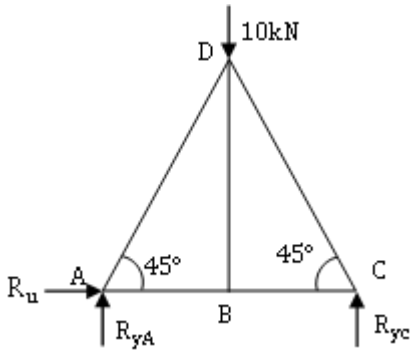
Q.26 - Q.55 Carry Two Mark each.

26. A truss is composed of members AB, BC, CD, AD and BD, as shown in the figure. A vertical load of 10kN is applied at point D. The magnitude of force (in kN) in the member BC is _____



[Ans. *]Range 5 to 5

Using point method



To determine R_{yc}

Toking moment about A =zero

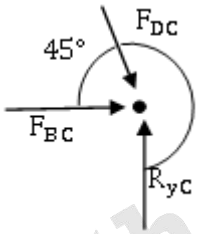
From geometry AB=BC=l

$\because \sum M_A = 0$

$\therefore 10 \times l = R_{yc} \times 2l$

$\therefore Ryc = 5kN$

Now taking FBD of p in C



Using lami's theorem

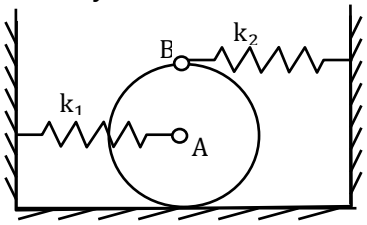
$$\frac{R_{yc}}{\sin 45°} = \frac{F_{BC}}{\sin 225°}$$

$$\frac{5}{\sin 45} = \frac{F_{Bc}}{\sin 225}$$

$F_{BC} = -5kN$

$\because |F_{BC}| = 5kN$

27. A uniform thin disk of mass 1kg and radius 0.1m is kept on a surface as shown in the figure. A spring of stiffness $k_1 = 400N/m$ is connected to the disk center A and another spring of stiffness $k_2 = 100N/m$ is connected at point B just above point A on the circumference of the disk. Initially, both the springs are unstretched. Assume pure rolling of the disk. For small disturbance from the equilibrium, the natural frequency of vibration of the system is _____ rad/s (round off to one decimal place).



[Ans. *]Range 23.0 to 24.0

As per given data

Disc mass, m = 1 kg

Radius, r = 0.1m

Torque equation about point 'o'

$I\theta + (k_1 \times r \times \theta)r + \ddot{(}k_2 \times 2r \times \theta)2r = 0$

$I \text{ about } O = \frac{mr^2}{2} + mr^2$

$I = \frac{3}{2} mr^2$

$\frac{3}{2} mr^2\ddot{\theta} + \left(k_1r^2 + k_2(4r^2\theta)\right)\theta = 0$

$$\omega_n = \left(\sqrt{\frac{k_1r^2 + 4r^2k_2}{\frac{3}{2}mr^2}}\right) = \sqrt{\frac{400(0.2)^2 + 4 \times 100 \times 0.2^2}{1.5 \times 1 \times 0.2^2}} = 23.094 \text{ rad/s}$$

28. Taylor's tool life equation is given by $VT^n = C$, where V is in m/min and T is in min. In a turning operation, two tools X and Y are used. For tool X, n=0.3 and C=60 and for tool Y, n=0.6 and C=90. Both the tools will have the same tool life for the cutting speed (in m/min, round off to one decimal place) of _____

[Ans. *]Range 38.0 to 42.0

Given data

$VT^n = c$

X	y
n=0.3	n=0.6
C=60	c=90

Tool life is same for the cutting speed

$V_x\, T_x^n = x\, V_x\, T_x^{0.3} = 60$

$V_y\, T_y^n = c\, V_y\, T_y^{0.6} = 60$

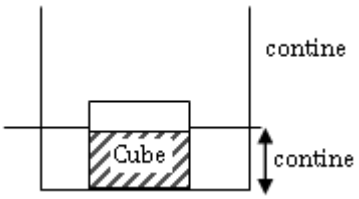
$VT^{0.3} = 60$

$VT^{0.6} = 90$

$T = 3.873$ min
$VT^{0.3} = 60$
$V = 40\text{m/min}$

29. A cube of side 100mm is placed at the bottom of an empty container on one of its faces. The density of the material of the cube is 800kg/m^3. Liquid of density 1000kg/m^3 is now poured into the container. The minimum height to which the liquid needs to be poured into the container for the cube to just lift up is _____mm.

[Ans. *]Range 80 to 80



$W = F_B$
$\rho_b V_b g = \rho_L V_d g$
$\rho_b \times A \times (100\text{mm}) \times g = \rho_L (A \times h)_g$
$h = \left(\frac{\rho_b}{\rho_L}\right) \times 100\text{mm} = 80\text{mm}$

30. The set of equations
$x + y + z = 1$
$ax - ay + 3z = 5$
$5x - 3y + az = 6$
has infinite solutions, if a=
(A) 3
(B) -4
(C) 4
(D) -3

[Ans. C]
$x + y + z = 1$
$ax - ay + 3z = 5$
$5x - 3y + az = 6$
Infinite solutions

$$\begin{pmatrix} 1 & 1 & 1 & \vdots & 1 \\ a & -a & 3 & \vdots & 5 \\ 5 & -3 & a & \vdots & 6 \end{pmatrix}$$

$R_2' : R_2 + R_1$

$$\begin{pmatrix} 1 & 1 & 1 & \vdots & 1 \\ a+1 & 1-a & 4 & \vdots & 6 \\ 5 & -3 & a & \vdots & 6 \end{pmatrix}$$

$\rho(A) = \rho(A:B) = 2$

$a = 4$

31. Consider a prismatic straight beam of length L=π m, pinned at the two ends as shown in the figure. The beam has a square cross-section of side p=6mm. The Young's modulus E=200GPa and the coefficient of thermal expansion $\alpha = 3 \times 10^{-6} K^{-1}$. The minimum temperature rise required to cause Euler bucking of the beam is _____K.

[Ans. *]Range 1 to 1

Buckling load $(P_e) = \frac{\pi^2 E I_{min}}{Le^2}$

Also,

P_e = readtion on ends $= \alpha . \Delta T . E . A$

Where A=cross sectional area

So, $\alpha . \Delta T . E\ A = \frac{\pi^2 E I_{min}}{Le^2}$

Since pinned ends so $L_e = L = \pi m$

$3 \times 10^{-6} \times \Delta T \times 6 \times 6 \times 10^{-6} = \frac{\pi^2 \times (6)^4 \times 10^{-12}}{\pi^2 \times 12}$

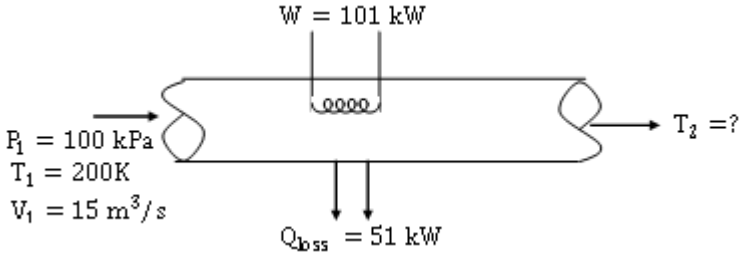
$\Delta T = 1k$

32. A gas is heated in a duct as it flows over a resistance heater. Consider a 101kW electric heating system. The gas enters the heating section of the duct at 100kPa and 27°C with a volume flow rate of 15 m^3/s. If heat is lost from the gas in the duct to the surroundings at a rate of 51kW, the exit temperature of the gas is _____

(Assume constant pressure, ideal gas, negligible change in kinetic and potential energies and constant specific heat: $C_p = 1 kJ/kg.K$: $R = 0.5\ kJ/kg.K$)

(A) 32°C
(B) 53°C
(C) 76°C
(D) 37°C

[Ans. A]



Since it is given an ideal gas and

$c_p = 1$ kJ/kgK

R = 0.5 kJ/kgK

at inlet $P_1\dot{V}_1 = \dot{m}RT1$

$$\dot{m} = \frac{P_1\dot{V}_1}{RT_1} = \frac{100 \times 15}{0.5 \times 300} = 10 \text{ kg/s}$$

Using SFEE

$\dot{m}h_1 + Q = \dot{m}h_2 + W$

$$h_1 + \frac{Q}{\dot{m}} = h_2 + \frac{W}{\dot{m}}$$

$$c_pT_1 - \left(\frac{51}{10}\right) = c_pT_2 - \frac{101}{10}$$

$$(T_2 - T_1)c_p = \frac{101 - 51}{10} = 5$$

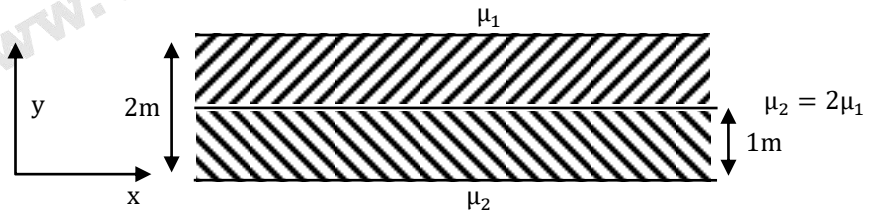
$$T_2 - T_1 = \frac{5}{c_p} = 5k$$

$T_2 = 300 + 5 = 305$K or32°c

33. Two immiscible, incompressible, viscous fluids having same densities but different viscosities are contained between two infinite horizontal parallel plates, 2m apart as shown below. The bottom plate is fixed and the upper plate moves to the right with a constant velocity of 3m/s. With the assumptions of Newtonian fluid, steady and fully developed laminar flow with zero pressure gradient in all directions, the momentum equations simplify to

$$\frac{d^2u}{dy^2} = 0$$

If the dynamic viscosity of the lower fluid μ_2 is twice that of the upper fluid μ_1 then the velocity at the interface (round off to two decimal places) is _____m/s.



[Ans. *]Range 0.98 to 1.02

$$\tau = d\frac{du}{dy}$$

$$= \mu \frac{V(y = h) - V(y = 0)}{h - 0}$$

for fluid 1

$$\tau = \mu, \frac{(3 - V)}{1}$$

for fluid 2

$$\tau = \mu_2 \frac{(V-0)}{1}$$
$$\Rightarrow \mu_1 \times \frac{(3-V)}{1} = \mu_2 \frac{V}{1}$$
$$\Rightarrow (3-V) = 2V$$
$$\Rightarrow 3 = 3V$$
$$\Rightarrow V = 1 m/sec$$

34. The value of the following definite integral is _____ (round off to three decimal places)

$$\int_1^e (x\ln x)dx$$

[Ans. *]Range 2.090 to 2.104

$$I = \int_1^\theta x\ln x dx$$

$$\text{Put } x = e^t, dx = e^t dt (\text{when } x = 1, t = 0; \text{ when } x = e, t = 1)$$

$$I = \int_0^1 t.e^t e^t dt = \int_0^1 t.e^{2t} dt$$

$$= [t\frac{e^t}{2} - \int \frac{e^{2t}}{2} dt]_0^1 = \left(t\frac{e^{2t}}{2} - \frac{e^{2t}}{4}\right)_0^1$$

$$\left(\frac{e^2}{2} - \frac{e^2}{4}\right) - \left(0 - \frac{1}{4}\right) = \frac{e^2+1}{4} = 2.097$$

35. If one mole of H_2 gas occupies a rigid container with a capacity of 1000litres and the temperature is raised from 27°C to 37°C, the change in pressure of the contained gas (round off to two decimal places), assuming ideal gas behavior is _____Pa. (R=8.314J/mol.K)

[Ans. *]Range 83.05 to 83.20

For an ideal gas

$$pV = n\bar{R}T$$

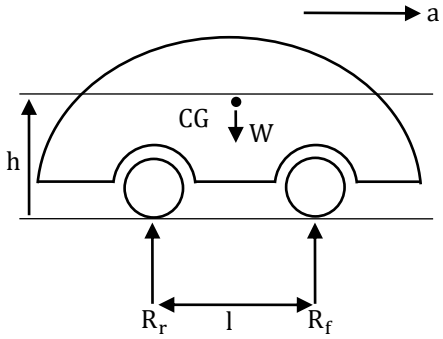
As the container is rigid, the heating process is isochoric theorems

$$pV = n\bar{R}T$$
$$\Rightarrow p = \frac{n\bar{R}T}{V}$$
$$p_1 = \frac{n\bar{R}T_1}{V}$$
$$p_2 = \frac{n\bar{R}T_2}{V}$$

Substituting $n = 1$ $v = 1$ we get $P_2 - P_1$

$$= \frac{1 \times 8.314 \times (42 - 32)}{1}$$
$$= 83.14 \text{ pa}$$

36. A car having weight W is moving in the direction as shown in the figure. The center of gravity (CG) of the car is located at height h from the ground, midway between the front and rear wheels. The distance between the front and rear wheels is l. The acceleration of the car is a and acceleration due to gravity is g. The reactions on the front wheels (R_f) and rear wheels (R_r) are given by



(A) $R_f = R_r = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a$

(B) $R_f = R_r = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$

(C) $R_f = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a; R_r = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$

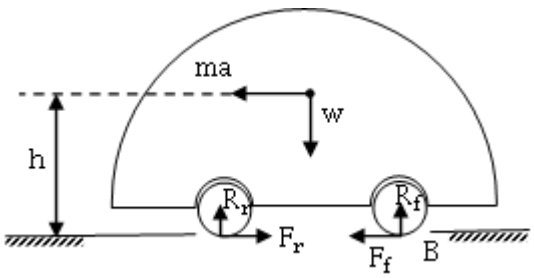
(D) $R_f = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a; R_r = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a$

[Ans. C]

Solution FBD of car after applying 'D' Alembert

$$m = \frac{W}{g} \cdots (i)$$

Now body is in dynamic equilibrium



So we can apply equation static equilibrium

$$\sum F_y = 0, W = R_r + R_f \cdots (ii)$$

$\sum M_A = 0$

Net clock moment = Net anticlockwise moment

$$W \times \frac{L}{2} = R - f \times l + \frac{W}{g}\, a \times h$$

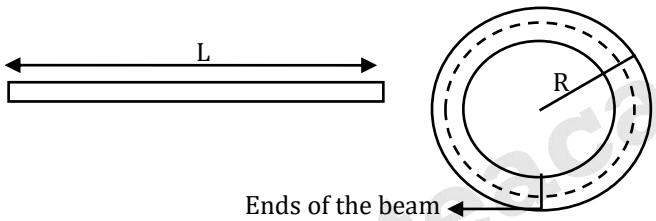
$$\therefore R - f = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right) a \cdots \text{(iii)}$$

Now from equation (ii)and (iii)

$$R_r = W - R_r$$

$$= \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right) a \cdots \text{(iv)}$$

37. Consider an elastic straight beam of length $L = 10\pi$ m, with square cross-section of side a=5mm and Young's modulus E=200GPa. This straight beam was bent in such a way that the two ends meet, to form a circle of mean radius R. Assuming that Euler-Bernoulli beam theory is applicable to this bending problem, the maximum tensile bending stress in the bent beam is _____MPa.



[Ans. *]Range 100 to 100

$L = 2\pi R$

$$R = \frac{L}{2\pi} = \frac{10\pi}{2\pi} = 5\text{m}$$

Using bending equation

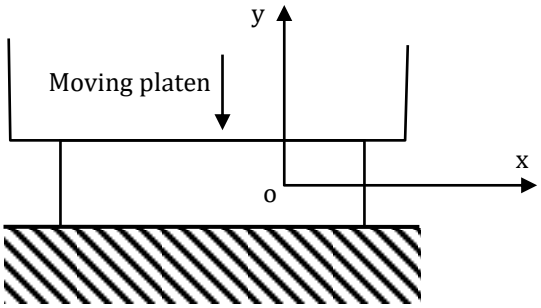
$$\frac{E}{R} = \frac{(\sigma_b)_{max}}{y_{max}}$$

$$(\sigma_b)_{max} = \frac{E}{R}\, y_{max}$$

$$= \frac{200 \times 10^3 \times 2.5 \times 0^{-3}}{5}$$

$(\sigma_b)_{max} = 100\text{MPa (Tensile)}$

38. A plane-strain compression (forging) of a block is shown in the figure. The strain in the z-direction is zero. The yield strength (S_y) in uniaxial tension compression of the material of the block is 300MPa and it follows the Tresca (maximum shear stress) criterion. Assume that the entire block has started yielding. At a point where $\sigma_x = 40$MPa (compressive) and $\tau_{xy} = 0$, the stress component σ_y is



(A) 340MPa (compressive)
(B) 340MPa (tensile)
(C) 260MPa (compressive)
(D) 260MPa (tensile)

[Ans. A]

According to Tresca's theory

$\sigma_{x+}P = 2K$

Where

$K = \frac{\sigma_0}{2}$ = flow shear stress

$= \frac{300}{2} = 150\text{MPa}$

And

$\sigma_x = -40\text{MPa}$

Now

$\sigma_x + P = 2K$

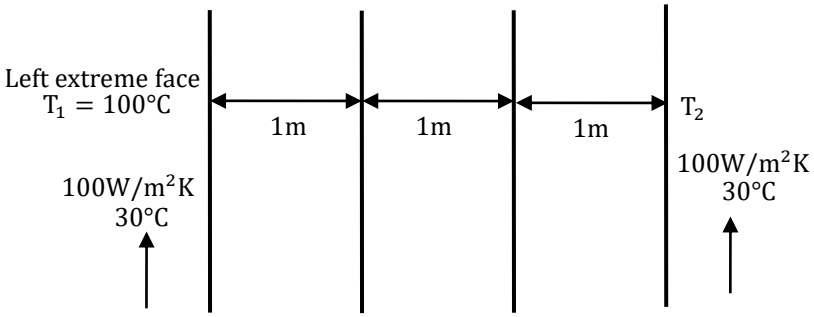
$-40 + P = 2 \times 150$

Or

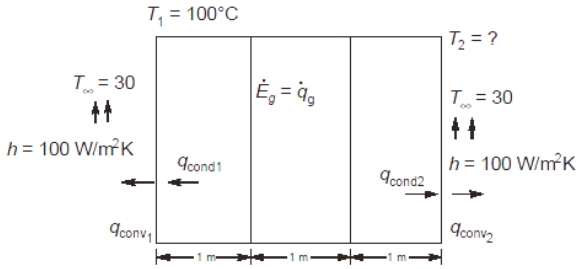
$P = 340\text{MPa}$

P is pressure. If $P = 340\text{MPa}$, stress(σ_y)will be -340MPa. i. e. 340MPa(compressive)

39. Three slabs are joined together as shown in the figure. There is no thermal constant resistance at the interfaces. The center slab experiences a non-uniform internal heat generation with an average value equal to 10000Wm^{-3}, while the left and right slabs have no internal heat generation. All slabs have thickness equal to 1m and thermal conductivity of each slab is equal to $5\text{Wm}^{-1}\text{K}^{-1}$. The two extreme faces are exposed to fluid with heat transfer coefficient $100\text{Wm}^{-2}\text{K}^{-1}$ and bulk temperature 30°C as shown. The heat transfer in the slabs is assumed to be one dimensional and steady and all properties are constant. If the left extreme face temperature T_1 is measured to be 100°C, the right extreme face temperature T_2 is _____ °C.



[Ans. *]Range 60 to 60



$\dot{E_g} = 10000 \times (L \times A)$

$= 10000 \times (1 \times 1) = 10000\ W$

$hA(T_1 - T_\infty) = q_{conv_1} = q_{cond1}$

$= 100 \times (100 - 30) = q_{cond1}$

$q_{cond1} = 7000\ W$

$q_{conv2} = hA(T_2 - T_\infty) = 100 \times 1 \times (T_2 - 30)$

$q_{conv2} = 100(T_2 - 30) = q_{cond2}$

At steady state

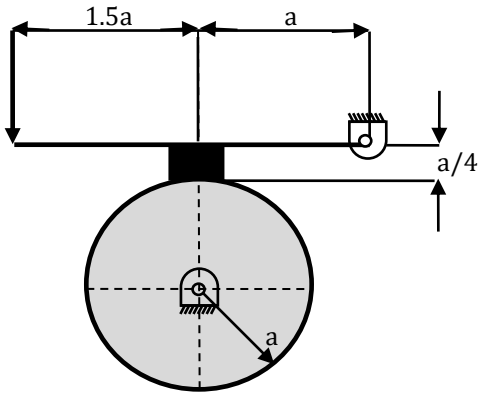
$\dot{E_g} = \dot{E_{out}}$

$\dot{E_g} = q_{cond1} + q_{cond2}$

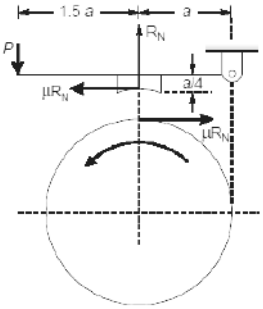
$10000 = 7000 + 100(T_2 - 30)$

$T_2 = \left(\frac{3000}{100}\right) + 30 = 60°C$

40. A single block brake with a short shoe and torque capacity of 250N-m is shown. The cylindrical brake drum rotates anticlockwise at 100rpm and the coefficient of friction is 0.25. The value of a in mm (round off to one decimal place), such that the maximum actuating force P is 2000N is _____



[Ans. *]Range 212.0 to 213.0



Drum equation $T_f = \mu R_N . a$

$250 = 0.25 \times R_N \times a$ ... ①

Lever equation

$$P \times 2.5\,a - \mu R_N \times \frac{a}{4} - R_N \times a = 0$$

$$R_N\left(1 + \frac{0.25}{4}\right) = 2000 \times 2.5$$

$R_N = 4705.882N$ ... ②

By eq ①

$250 = 0.25 \times 4705.882 \times a = 212.5mm$

41. Match the following sand mold casting defects with their respective causes.

Defect		Cause	
P	Blow hole	1	Poor collapsibility
Q	Misrun	2	Mold erosion
R	Hot tearing	3	Poor permeability
S	Wash	4	Insufficient fluidity

(A) P-3, Q-4, R-2, S-1
(B) P-2, Q-4, R-1, S-3
(C) P-4, Q-3, R-1, S-2
(D) P-3, Q-4, R-1, S-2
[Ans. D]

42. The rotor of a turbojet engine of an aircraft has a mass 180kg and polar moment of inertia 10kgm^2 about the rotor axis. The rotor rotates at a constant speed of 1100rad/s in the clockwise direction when viewed from the front of the aircraft. The aircraft while flying at a speed of 800km per hour takes a turn with a radius of 1.5km to the left. The gyroscopic moment exerted by the rotor on the aircraft structure and the direction of motion of the nose when the aircraft turns are
(A) 1629.6N.m and the nose goes up
(B) 1629.6N.m and the nose goes down
(C) 162.9N.m and the nose goes up
(D) 162.9N.m and the nose goes down
[Ans. B]

$I = 10\ kg - m^2$

Angular velocity of 8 pin $\omega = 1100\frac{rad}{s}$ (clock wise)

$V_p = 800km/h$ Radius of turn $= 1.5km$

$$\therefore \omega_p = \frac{V_p}{R} = \frac{800 \times \frac{5}{18}}{1.5 \times 1000} = 148\ rad/s$$

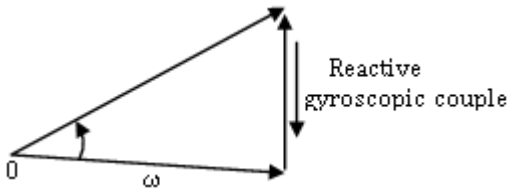
Gyroscopic moment $C = I\omega\ \omega_p$

$= 10 \times 1100 \times 148$

$= 1629.62\ N - m$

effect During left turn if viewed from rear

(LEFT TURN), Rotation sense(c. w)



Nose ↑ tail ↓

43. In ASA system, the side cutting and end cutting edge angles of a sharp turning tool are 45° and 10° respectively. The feed during cylindrical turning is 0.1mm/rev. The center line average surface roughness (in μm, round off to one decimal place) of the generated surface is _____

[Ans. *]Range 3.5 to 3.9

Given data

$SCEA = 45°$

$ECEA = 10°$

$f = 0.1\frac{mm}{R_{eq}}$

$CLA(\mu m) =$_____

Average value of increases in turing operation without nose radius is given as

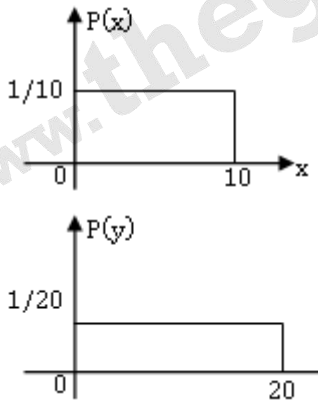
$$H_{avg} = \frac{f}{4(\tan SCEA + \cot ECEA)}$$

$CLA = H_{avg} = 3.747\mu m$

44. The variable x takes a value between 0 and 10 with uniform probability distribution. The variable y takes a value between 0 and 20 with uniform probability distribution. The probability of the sum of variables (x+y) being greater than 20 is

(A) 0
(B) 0.25
(C) 0.50
(D) 0.33

[Ans. B]



$p(x + y > 20)$

$y > 20\,x$

$$\int_0^{10} \int_{20-z}^{20} p\ (x, y)dy\,dx$$

$p(x, y) = p(x)p(y)$

$$\int_0^{10} \int_{20-x}^{20} \frac{1}{10} \times \frac{1}{20} \, dy \, dx$$

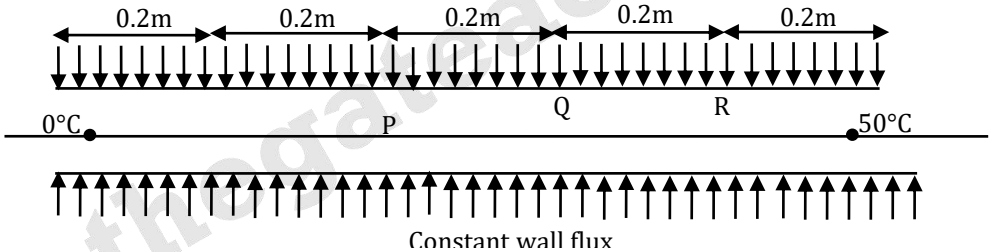
$$\frac{1}{200} \int_0^{10} (y)_{20-x}^{20} \, dx = \frac{1}{200} \int x \, dx$$

$$\frac{1}{200} \left(\frac{x^2}{2}\right)_0^{10}$$

$$\frac{1}{400} \times 100 = \frac{1}{4} = 0.25$$

45. The wall of a constant diameter pipe of length 1m is heated uniformly with flux q^n by wrapping a heater coil around it. The flow at the inlet to the pipe is hydrodynamically fully developed. The fluid is incompressible and the flow is assumed to be laminar and steady all through the pipe. The bulk temperature of the fluid is equal to 0°C at the inlet and 50°C at the exit. The wall temperature is measured at three locations P, Q and R as shown in the figure. The flow thermally develops after some distance from the inlet. The following measurements are made:

Point	P	Q	R
Wall Temp (°C)	50	80	90



Among the locations P, Q and R, the flow is thermally developed at

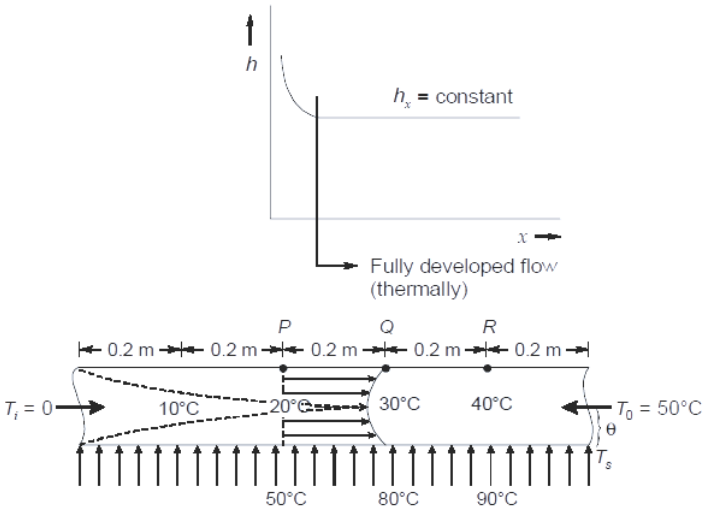
(A) P and Q only

(B) R only

(C) Q and R only

(D) P, Q and R

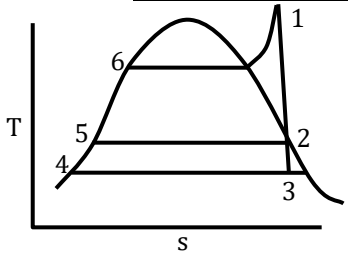
[Ans. C]



$dq = h_x \times 1 \times (T_w - T_b)$
$dq = constant$
$hx = constant$
$(T_w - T_b) = constant$
Also,
$dq = \dot{m}c_p dT_b$
$dq = c$
$dT_b = constant$
T_b varies linearly with respect to x
T_w also varies linearly with respect to x.
Hence Q, R in fully developed region.

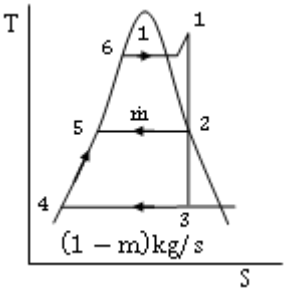
46. A steam power cycle with regeneration as shown below on the T-s diagram employs a single open feed water heater for efficiency improvement. The fluids mix with each other in an open feed water heater. The turbine is isentropic and the input (bleed) to the feed water heater from the turbine is at state 2 as shown in the figure. Process 3-4 occurs in the condenser. The pump work is negligible. The input to the boiler is at state 5. The following information is available from the steam tables:

State	1	2	3	4	5	6
Enthalpy (kJ/kg)	3350	2800	2300	175	700	1000



The mass flow rate of steam bled from the turbine as a percentage of the total mass flow rate at the inlet to the turbine at state 1 is _____

[Ans. *]Range 20 to 20



From energy balance equation

$\dot{m}h_2 + (1-\dot{m})h_4 = h_5$

$\dot{m}h_2 + \dot{m}h_4 + h_4 = h_5$

$\dot{m}(h_2 + h_4) = h_5 - h_5$

$$\dot{m} = \frac{h_5 - h_4}{h_2 - h_4}$$

$$\dot{m} = \frac{700 - 175}{2800 - 175} \times 100 = 0.2 \text{ or } 20\%$$

47. At a critical point in a component, the state of stress is given as $\sigma_{xx} = 100\text{MPa}$, $\sigma_{yy} = 220\text{MPa}, \sigma_{xy} = \sigma_{yx} = 80\text{MPa}$ and all other stress components are zero. The yield strength of the material is 468MPa. The factor of safety on the basis of maximum shear stress theory is _____ (round off to one decimal place).

[Ans. *]Range 1.7 to 1.9

As per given data

$\sigma_{xx} = 100\text{MPa}$

$\sigma_{yy} = 220\text{MPa}$

$\sigma_{xy} = \sigma_{yx} = 80\text{MPa}$

Principal stresses are

$$\sigma_{1,2} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \sigma_{xy}^2}$$

$$= \left(\frac{100 + 220}{2}\right) \pm \sqrt{\left(\frac{100 - 220}{2}\right)^2 + 80^2} = 160 \pm 100$$

$\sigma_1 = 160 + 100 = 260\text{MPa}$

$\sigma_2 = 160 - 100 = 60\text{ MPa}$

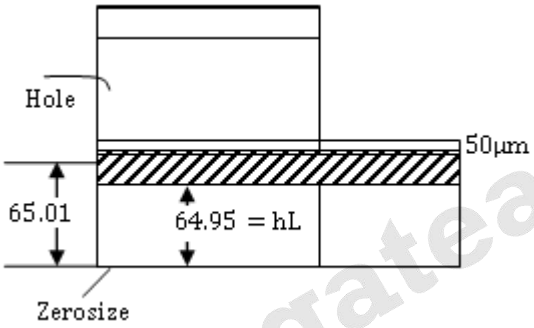
Both principal stresses are like in nature.

According to maximum shear stress theory.

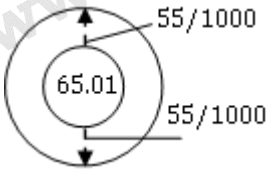
Maximum shear stress $= [\max\left(\frac{\sigma_1 - \sigma_2}{2}\right), \left(\frac{\sigma_1}{2}\right), \left(\frac{\sigma_2}{2}\right)]$

$$\tau_{max} = \frac{\sigma_1}{2}$$
$$\frac{\sigma_{yt}}{FOS \times 2} = \frac{\sigma_1}{2}$$
$$FOS = \frac{\sigma_{yt}}{\sigma_1} = \frac{468}{260} 1.8$$

48. A circular shaft having diameter $65.00^{+0.01}_{-0.05}$mm is manufactured by turning process. A 50μm thick coating of TiN is deposited on the shaft. Allowed variation in TiN film thickness is $\pm$5μm. The minimum hole diameter (in mm) to just provide clearance fit is
(A) 65.10
(B) 65.12
(C) 64.95
(D) 65.01
[Ans. B]
Give data



$\frac{uD}{LD}$ of coating is given $\pm$ 5μm
For clearance fit
$(D_{min})_{hole} > (D_{max})_{shaft}$



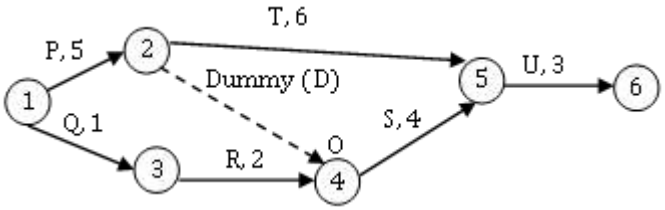
$$(D_{min})_{hole} = 65.01 + 2 \times \frac{55}{1000}$$
$(D_{min})_{hole} = 65.12$ clearance fit

49. A project consists of six activities. The immediate predecessor of each activity and the estimated duration is also provided in the table below:

Activity	Immediate predecessor	Estimated duration (weeks)
P	-	5
Q	-	1
R	Q	2
S	P,R	4
T	P	6
U	S,T	3

If all activities other than S take the estimated amount of time, the maximum duration (in weeks) of the activity S without delaying the completion of the project is _____

[Ans. *]Range 6 to 6



Critical path:

1. P − T − U = 14 weeks without compromising the project completion time activity S has to be increased in such a way that maximum completion time remain 14 weeks only

So other paths

2. P − D − (S) − U → 12 days
3. Q − R − (S) − U → 10 days

   Hence by second path activity can be delayed maximum by 2 days only

   Hence maximum duration of activity (S) =6 weeks

50. In a UTM experiment, a sample of length 100mm was loaded in tension until failure. The failure load was 40kN. The displacement measured using the cross-head motion at failure was 15mm. The compliance of the UTM is constant and is given by 5×10^{-8}m/N. The strain at failure in the sample is _____%.

[Ans. *]Range 12 to 14

In UTM experiment under tension.

L = 100 mm

Failure load (P) = 40 kN

Compliance of UTM is constant = $\frac{L}{AE} = 5 \times \frac{10^{-8}m}{N} = \text{Constant}$

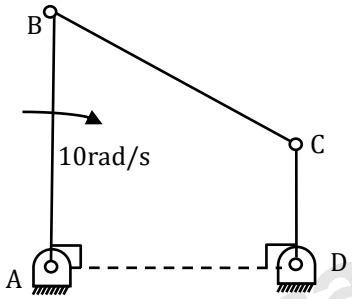
Strain at failure = ?

As we know, $\delta = \frac{PL}{AE}$

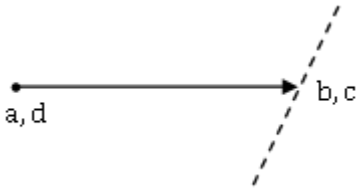
$a = \delta\frac{AE}{L}$

$P = \text{Constant}(\delta)$
Linear Relationship, So
$\frac{\delta}{L} = \frac{P}{AE}$
$\text{Strain} = \frac{P}{AE} \times \frac{L}{L} = P \times \left(\frac{L}{AE}\right) \times \frac{1}{L}$
$\text{Strain} = P \times \text{compliance} \times \frac{1}{L}$
$= \frac{40 \times 10^3 \times 5 \times 10^{-8}}{100 \times 10^{-3}} = 2 \times 10^{-2}$
$2 \times 10^{-2} \times 100\% = 2\%$

51. In a four bar planar mechanism shown in the figure AB=5cm, AD=4cm and DC=2cm. In the configuration shown both AB and DC are perpendicular to AD. The bar AB rotates with an angular velocity of 10rad/s. The magnitude of angular velocity (in rad/s) of bar DC at this instant is



(A) 0
(B) 10
(C) 15
(D) 25
[Ans. D]
Draw velocity diagram for given mechanism



$V_{AB} = V_{CD}$
$AB \times \omega_{AB} = CD \times \omega_{CD}$
$5 \times 10 = 2 \times \omega_{CD}$
$\omega_{CD} = 25 \text{ rad/s}$

52. In orthogonal turning of a cylindrical tube of wall thickness 5mm the axial and the tangential cutting forces were measured as 1259N and 1601N respectively. The measured chip thickness after machining was found to be 0.3mm. The rake angle was 10° and the axial feed was 100mm/min. The rotational speed of the spindle was 1000rpm. Assuming the material to be perfectly plastic and Merchant's first solution, the shear strength of the material is closest to

(A) 722MPa
(B) 875MPa
(C) 920MPa
(D) 200MPa

[Ans. A]

Give data

Tube of wall thickness =5mm=b

Faxial=1259 N

N=1000rpm

$F_c$or $F_y = 160\ 1N$

F_c = cutting force

$t_2 = 0.3mm$

$\alpha = 10°$

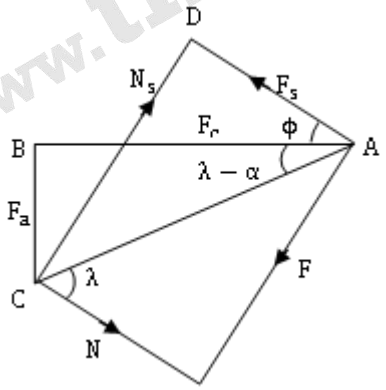
$\text{Axial feed} = \frac{100mm}{min} = fn$

τ_s = shear strength of matrial

$\tau_s = \frac{F_s}{\sin\phi}$

t_1 can be considered as feed

From merchant circle



$\frac{100\frac{mm}{min}}{1000} = f = 0.1\ mm/Rer$

$f = 0.1\frac{mm}{Rer}$

$\tan\lambda - 2 = \frac{Fa}{Fe}$ from ΔABC

$\lambda tam = 48.181$

$\tau_s = \frac{F_s}{\frac{bt_1}{\sin\phi}} = \frac{\frac{1103.7}{005\times0.1\times10^{-3}}}{\sin 19.134} = 723.5$ MPa

From ΔACD we can culculate F_s

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

$R = \sqrt{F_a^2 + F_T^2} = 2043.815$

$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$ $\phi = 19.134$

ϕ = shear plane angle

r = chipthickness ratio $= \frac{t_1}{t_2} = \frac{0.1}{0.3}$

$= 0.332$

$F_s = R\cos(\phi + \lambda - \alpha)$

$F_s = 1103.7N$

$\tau_s = 722$ MPa {approximated}

53. A harmonic function is analytic if it satisfies the Laplace equation. If $u(x,y) = 2x^2 - 2y^2 + 4xy$ is a harmonic function then its conjugate harmonic function $v(x,y)$ is

(A) $4xy - 2x^2 + 2y^2 +$ constant

(B) $2x^2 - 2y^2 + xy +$ constant

(C) $4y^2 - 4xy +$ constant

(D) $-4xy + 2y^2 - 2x^2 +$ constant

[Ans. A]

Let f (z) = u + iv is an analytic function where u is harmonic then v is called its harmonic conjugate. Here u = 2x2 – 2y 2 + 4xy i.e. real part is given, so by using Milne-Thomson method

Step 1: $\frac{\partial u}{\partial x} = 4x + 4y = \emptyset_1(x,y)$

Step 2: $\emptyset_1(z,0) = 4z$

Step 3: $\frac{\partial U}{\partial Y} = -4y + 4x = \emptyset_2(x,y)$

Step 4: $\emptyset_2(z,0) = 4z$

Step 5: $f(z) = \int[\emptyset_1(z,0) - i\emptyset_2(z,0)] + c$

$= \int(4z - i4z)dz + c = 4(1-i)\frac{z^2}{2} + c$

$= 2(1-i)[x^2 - y^2 + 2ixy] + c$

$f(z) = (2x^2 - 2y^2 + 4xy) + i(4xy - 2x^2 + 2y^2 + c) = u + iv$

Hence harmonic conjugate, $v = 4xy - 2x^2 + 2y^2 +$ constant

54. Five jobs (J1, J2, J3, J4 and J5) need to be processed in a factory. Each job can be assigned to any of the five different machines (M1, M2, M3, M4 and M5). The time durations taken (in minutes) by the machines for each of the jobs are given in the table. However, each job is assigned to a specific machine in such a way that the total processing time is minimum. The total processing time is _____minutes.

	M1	M2	M3	M4	M5
J1	40	30	50	50	58
J2	26	38	60	26	38
J3	40	34	28	24	30
J4	28	40	40	32	48
J5	28	32	38	22	44

[Ans. *]Range 146 to 146

Row reduction

10	0	20	20	28
0	12	24	0	12
16	12	4	0	6
0	12	12	4	20
26	10	16	0	22

Column reduction

10	[0]	16	20	22
0	12	20	0	6
16	12	[0]	0	0
[0]	12	8	4	14
6	10	12	[0]	16

$TC = 30 + 38 + 28 + 28 + 22$

$= 146$

55. A gas turbine with air as the working fluid has an isentropic efficiency of 0.70 when operating at a pressure ratio of 0.3. Now the pressure ratio of the turbine is increased to 5, while maintaining the same inlet conditions. Assume air as a perfect gas with specific heat ratio $\gamma = 1.4$. If the specific work output remains the same for both the cases, the isentropic efficiency of the turbine at the pressure ratio of 5 is _____ (round off to two decimal places)

[Ans. *]Range 0.50 to 0.52

$$\frac{P_3}{P_{4s}} = 3$$

$$\frac{P_3'}{P_{4s}} = 5$$

$$w_{net_1} = c_p T_3 \left\{1 - \frac{1}{3^{\gamma - \frac{1}{r}}}\right\} 0.7$$

$$w_{net_1} = c_p T_3 \left\{1 - \frac{1}{5^{\gamma - \frac{1}{r}}}\right\} \eta$$

$$w_{net_1} = w_{net_2}$$

$$\eta = \frac{(0.7)\left\{1 - \frac{1}{3^{\gamma - \frac{1}{r}}}\right\}}{\left\{1 - \frac{1}{5^{\gamma - \frac{1}{r}}}\right\}} = 0.514$$

Consider it is asked only for turbine portion as for full cycle, data is not sufficient.