IES MASTER

Institute for Engineers (IES/GATE/PSUs)

GATE 2019

MECHANICAL ENGINEERING

Detailed Solution

EXAM DATE: 02-02-2019

MORNING SESSION (09:30 AM-12:30 PM)

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1. John Thomas, an _____ writer, passed away in 2018.

(a) imminent (b) dominant

(c) eminent (d) prominent

Ans. (c)

2. The minister avoided any mention of the issue of women's reservation in the private sector. He was accused of _____ the issue.

(a) collaring (b) belting

(c) tying (d) skirting

Ans. (d)

3. The sum and product of two integers are 26 and 165 respectively. The difference between these two integers is _____.

(a) 4 (b) 2

(c) 6 (d) 3

Ans. (a)

Sol. Prime factorisation of

$$165 = 3 \times 5 \times 11$$

$$165 = 15 \times 11$$

So the two numbers whose sum is 26 and multiplication is 165 is 15 and 11

$$\text{difference} = 15 - 11 = 4$$

Option (a) 4 is correct

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

(a) Have, would (b) Have, wouldn't

(c) Had, would (d) Had, wouldn't

Ans. (c)

5. A worker noticed that the hour hand on the factory clock had moved by 225 degrees during her stay at the factory. For how long did she stay in the factory ?

(a) 8.5 hours

(b) 3.75 hours

(c) 4 hours and 15 minutes

(d) 7.5 hours

Ans. (d)

Sol. $\because$ $360° = 12$ hours

$\therefore$ $1° = \dfrac{12}{360}$ hours

$\therefore$ $225° = \dfrac{12 \times 225}{360}$ hours

$= 7.5$ hours

Option (d) 7.5 hours is correct

6. 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) 9:16 (b) 47:53

(c) 11:14 (d) 37:63

Ans. (b)

Sol.

Let first part = x

So second part = 100,000 – x

According to question

$$\left[0.1x + 0.12(100{,}000 - x)\right] - \left[0.12x + 0.1(100{,}000 - x)\right] = 120$$

$$0.2x - 0.24x + 1200 - 1000 = 120$$

$$-0.04x = -1880$$

$$x = 47000$$

$$\frac{x}{100{,}000 - x} = \frac{47000}{53000} = \frac{47}{53}$$

7. 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)

Sol.

If prisoner make the statement "I wil be shot" then only judge have no option and prisoner will be freeze so option (3) I will be shot is correct choice

8. 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) R is the father of Y

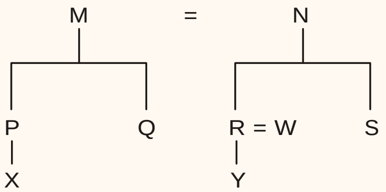
(b) W is the wife of R

(c) M is the grandmother of Y

(d) W is the wife of P

Ans. (d)

Sol.



From the family tree option (d) W is the wife of P can'not possible

So option (d) W is the wife of P is correct choice

9. Congo was named 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 Portuguese alteration of Nzadi o Nzere, a local African term meaning 'River that swallows Rivers'. Zaire was the Portuguese name for the Congo river in the 16th and 17 centuries.

Which one of the following statements can be inferred from the paragraph above ?

(a) The term Nzadi o Nzere was of Portuguese origin

(b) As a dictator Mobuto ordered the Portuguese to alter the name of the river to Zaire

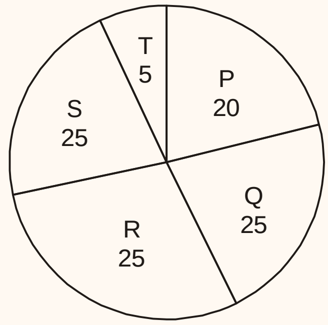
(c) Mobuto's desire to Africanise names was prevented by the Portuguese

(d) Mobuto was not entirely successful in Africanising the name of his country

Ans. (d)

10. 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 at skill levels P, Q and R remained unchanged during this period. If the exmployment at skill level S increased by 40% from 2010 to 2016, how many employees were there at skill level T in 2016 ?

Percentage shear of skills in 2010

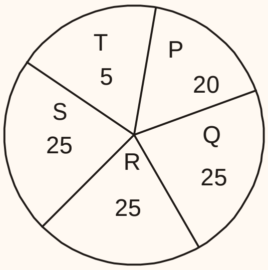


(a) 72 (b) 60
(c) 30 (d) 35

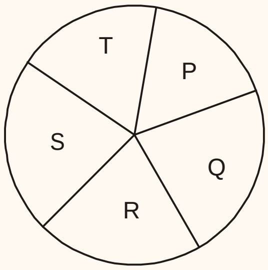
Ans. (b)

Sol.

2010



2016



$$600 \xrightarrow{\uparrow 15\%} 1.15 \times 600 = 690$$

$$P = 20\% = 120 \xrightarrow{\uparrow 0\%} 120$$

$$Q = 25\% = 150 \xrightarrow{\uparrow 0\%} 150$$

$$R = 25\% = 150 \xrightarrow{\uparrow 0\%} 150$$

$$S = 25\% = 150 \xrightarrow{\uparrow 40\%} 210$$

$$T = 5\% = 30 \longrightarrow ?$$

Employees at skill level T

$$= 690 - (120 + 150 + 150 + 210)$$

$$= 60$$

Option (b) 60 is correct

11. Water flows though 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. (3)

Sol. $$\vec{V} = \left(\frac{4}{t} + x + y\right)\hat{j}\,\frac{m}{s}$$

$$\vec{V} = u\hat{i} + v\hat{j} + w\hat{k}$$

$$u = 0,\; w = 0$$

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

$$\vec{a} = \vec{a}_x\,\hat{i} + \vec{a}_y\,\hat{j} + \vec{a}_z\,\hat{k}$$

$$\vec{a}_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t} = 0$$

$$\vec{a}_z = u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} + \frac{\partial w}{\partial t} = 0$$

$$\vec{a}_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{dv}{\partial z} + \frac{\partial v}{\partial t}$$

$$= v\frac{\partial v}{\partial y} + \frac{\partial v}{\partial t}$$

$$= \left(\frac{4}{t} + x + y\right) \times 1 + \left(-\frac{4}{t^2}\right)$$

$$\vec{a}_y = \left(\frac{4}{t} + x + y - \frac{4}{t^2}\right)\hat{j}$$

At (x,y) = 1,1 and t = 2 sec.

Total acceleration

$$\vec{a} = \vec{a}_y = \left(\frac{4}{2} + 1 + 1 - \frac{4}{4}\right) = 3\frac{m}{s^2}$$

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

(a) 0.36 kN (b) 2.78 kN
(c) 0.73 kN (d) 1.39 kN

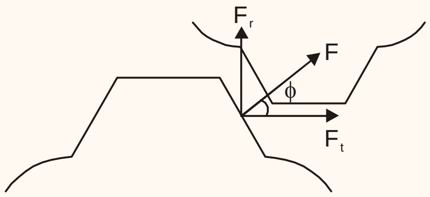
Ans. (c)

Sol. $$\phi = 20°$$

$$P = 20 \text{ kW},\; w = 200 \text{ rad/s}$$

$$PCD = 100 \text{ mm}$$

$$F_r = ?$$



$$F\cos\phi = F_t$$

$$F\sin\phi = F_r$$

$$\frac{F_r}{F_t} = \tan\phi$$

$$F_r = F_t\tan\phi$$

$$T = \frac{P}{\omega} = \frac{20\times1000}{200} = 100\,\text{N.m.}$$

$$T = F_t \times r$$

$$\Rightarrow \quad F_t = \frac{T}{r} = \frac{100}{\frac{100}{2}\times10^{-3}} = 2000\,\text{N}$$

$$F_r = F_t\tan\phi = 2000\tan 20$$

$$= 727.9\ \text{N}$$

$$= 0.73\ \text{kN}$$

13. 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) 510 (b) 530

(c) 536.67 (d) 490

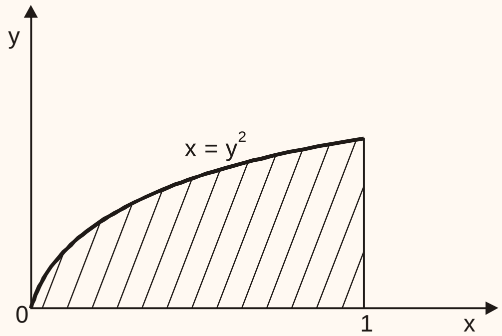
Ans. **(a)**

Sol. Three month moving average.

Forecast of the product for the month of september

$$F = \frac{495+475+560}{3} = 510$$

14. A parabola $x = y^2$ with $0 \le x \le 1$ 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

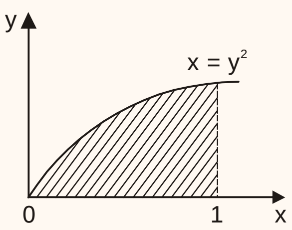


(a) 2π (b) $\frac{\pi}{2}$

(c) $\frac{\pi}{4}$ (d) π

Ans. **(b)**

Sol.



$$V = \int_0^1 \pi y^2\,dx$$

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

$$= \left.\frac{\pi x^2}{2}\right|_0^1 = \frac{\pi}{2}$$

15. As per common design practice, the three types of hydraulic turbines, in descending order of flow rate, are

(a) Pelton, Francis, Kaplan

(b) Francis, Kaplan, Pelton

(c) Pelton, Kaplan, Francis

(d) Kaplan, Francis, Pelton

Ans. **(d)**

Sol. In descending order of flow rate.

Kaplan > Francis > Pelton

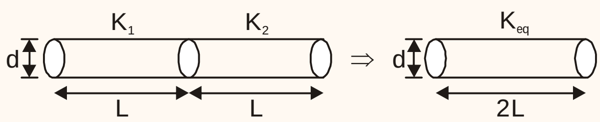
16. A slender rod of length L, diameter d (L >> d) and thermal conductivity k_1 is joined with another rod of identical dimensions, but of thermal conductivity k_2, to form a composite cylindrical rod of length 2L. The heat transfer in radial direction and contact resistance are negligible. The effective thermal conductivity of the composite rod is

(a) $\dfrac{2k_1k_2}{k_1+k_2}$ (b) $\sqrt{k_1k_2}$

(c) $\dfrac{k_1k_2}{k_1+k_2}$ (d) k_1+k_2

Ans. **(a)**

Sol.



Heat transfer in radial direction and contact resistance are negligible.

Series connection

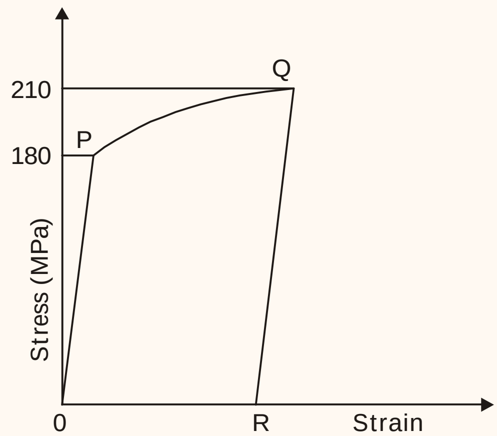
$$(R_{th})_{eq} = R_1 + R_2$$

$$\frac{2L}{A k_{eq}} = \frac{L}{AK_1} + \frac{L}{AK_2}$$

$$\frac{2}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2}$$

$$\left(K_{eq} = \frac{2K_1K_2}{K_1+K_2}\right)$$

17. 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 t which the material yields again is _____ MPa.



Ans. **(210)**

Sol. As the point loaded beyond the yield point is unloaded completely and reloaded then because of strain hardening (residual strain remains in body) increase the yield strength.

In this case material with start yielding from point ‘R’ instead of ‘P’.

18. 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 cycle loading is _____ (round off to one decimal place).

Ans. **(–0.2)**

Sol.

$$\sigma_{mean} = +140 \text{ MPa}$$

$$\sigma_{min} = -70 \text{ MPa}$$

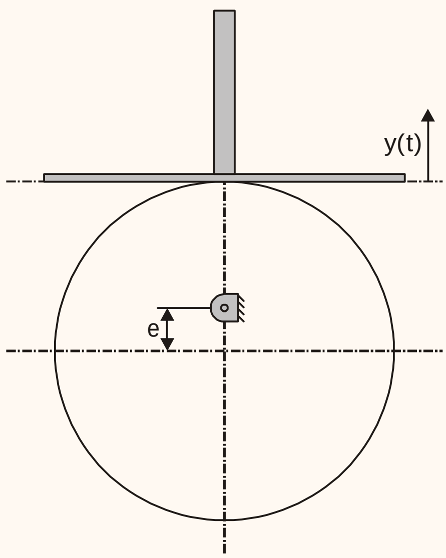
$$\sigma_{mean} = \frac{\sigma_{max} + \sigma_{min}}{2} = 140$$

$$\frac{\sigma_{max} - 70}{2} = 140$$

$$\sigma_{max} = 350 \text{ MPa}$$

$$\frac{\sigma_{min}}{\sigma_{max}} = \frac{-70}{350} = -0.2$$

19. 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.



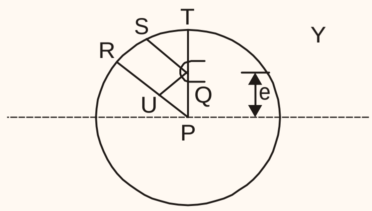
The vertical position of the follower face, y(t) is given by

(a) $e\sin\omega t$ (b) $e(1+\cos 2\omega t)$

(c) $e\sin 2\omega t$ (d) $e(1-\cos\omega t)$

Ans. **(d)**

Sol.



Radius = R′

As the follower starts moving, the displacement Y can be shown as marked in the diagram

$$Y = QS - QT$$

$$= RU - QT \qquad (\because QS \parallel RU)$$

$$= (PR - PV) - QT \qquad \text{...(i)}$$

$$PR = R'$$

$$\Rightarrow \quad PU = e\cos\theta$$

$$QT = (R' - e) \qquad \text{from geometry}$$

Putting the above values in equation (i)

$$Y = e(1 - \cos\theta)$$

$$\boxed{Y = (1 - \cos\omega t)}$$

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

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

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

Ans. **(a)**

Sol. $\frac{dy}{dx} + 7x^2y = 0, \quad y(0) = \frac{3}{7}, \quad y(1) = ?$

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

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

$$ln\,y = -\frac{7x^3}{3}+C$$

$$y = e^{-\frac{7x^3}{3}+C}$$

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

$$C = ln\left(\frac{3}{7}\right)$$

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

$$ln\,y - ln\left(\frac{3}{7}\right) = -\frac{7x^3}{3}$$

$$ln\left(\frac{7y}{3}\right) = -\frac{7x^3}{3}$$

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

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

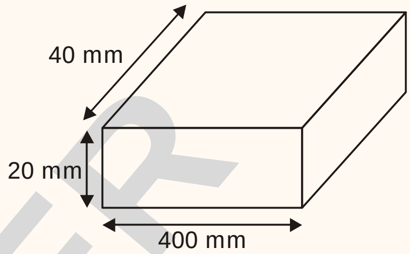
21. The length, width and thickness of a steel sample are 400 mm, 410 mm, 40 mm and 20 mm, respectively. Its thickness needs to be uniformly reduced by 2 mm in a single pass by using horizontal slab miling. The miling cutter (diameter : 100 mm, width ; 50 mm) has 20 teeth and rotates at 1200 rpm. The feed per tooth is 0.05 mm. 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) 14 mm, 18.4 s

(c) 14 mm, 21.4 s (d) 21 mm, 28.9 s

Ans. (c)

Sol.



Depth of cut $\Rightarrow$ (d = 2 mm) Milling cutter,

$$D = 100 \text{ mm}$$
$$W = 50 \text{ mm}$$
$$Z = 20 \text{ tooth, } N = 1200 \text{ rpm}$$
$$f_t = 0.05 \text{ mm/tooth rev}$$
$$f = z \times f_t = 20 \times 0.05 \text{ mm/rev}$$
$$= 1 \text{ mm/rev}$$

$$\text{Overtravel} = \text{Approach (A)} = \sqrt{d(D-d)}$$

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

Total length covered by tool

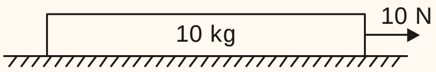
$$L + 2A = 400 + 2 \times 14 = 428 \text{ mm}$$

Time for one pass,

$$t = \frac{L}{fN}$$

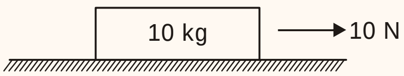
$$= \frac{428}{1\times\left(\frac{1200}{60}\right)} = 21.4\,\text{sec}$$

22. A block mass 10 kg rests on a horizontal floor. The acceleration due to gravity is 9.81 m/s². 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. **(10)**

Sol.



$$\mu = 0.2$$

$$g = 9.81 \text{ m/s}^2$$

$$M = 10 \text{ kg}$$

$$(f_s)_{max} = \mu Mg = 0.2 \times 10 \times 9.81$$

$$= 19.62 \text{ N}$$

$$(F_s)_{max} > \text{Force applied}$$

$$(F_s) = 10 \text{ N}$$

23. 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.

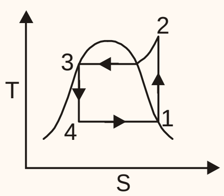
(b) Coefficient of performance is the same as that of the original cycle.

(c) Coefficient of performance is lower than that of the original cycle.

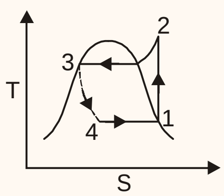
(d) Refrigerating effect is lower than that of the original cycle.

Ans. **(a)**

Sol. V-C-R-S cycle



Isentropic Expander



Throttling process

Both cycle required same amount of work input but by use of Isentropic expander, we can get more amount of refrigeration effect, hence

$$\left((COP)_{\text{modified cycle}} > (COP)_{\text{original cycle}}\right)$$

24. 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) 3 (b) 0

(c) 1 (d) 2

Ans. **(c)**

Sol.
$$|P - \lambda I| = \begin{vmatrix} 1-\lambda & 1 & 0 \\ 0 & 1-\lambda & 1 \\ 0 & 0 & 1-\lambda \end{vmatrix}$$

$$(1-\lambda)\left[(1-\lambda)(1-\lambda) - 0\right] = 0$$

$$\lambda = 1,1,1$$

No. of distinct eigen value = 1.

25. 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) $Nu_q = (Nu_T)^2$

(c) $Nu_q < Nu_T$ (d) $Nu_q > Nu_T$

Ans. **(d)**

Sol. $(Nu)_q$ for constant wall heat flux and $(N_u)_T$ at constant wall temperature for a hydrodynamically and thermally fully developed laminar flow through a circular

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	R.T. :	
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	R.T. :	TH-2, MS-1, HT-1
31st Mar 2019	**N.T.** :	MECH-1, MECH-2, HT-2, RE-1
	R.T. :	RAC-1, RAC-2, MS-2
07th Apr 2019	**N.T.** :	FMM-2, PPE-1,RSE-2
	R.T. :	HT-1, HT-2, TH-1, FMM-1, IE-2
14th Apr 2019	**N.T.** :	ICE-1,ToM-2, MR-1
	R.T. :	FMM-2, RSE-1, RSE-2, PPE-1
21st Apr 2019	**N.T.** :	ToM-1, MR-2, PROD-1
	R.T. :	MS-1, MECH-1, MECH-2,TH-1
28th Apr 2019	**N.T.** :	IE-1, PPE-2, FMM-3,
	R.T. :	PPE-1, MS-2, HT-1, PROD-1,ToM-1, ICE-1
05th May 2019	**N.T.** :	PPE-3, PROD-2
	R.T. :	RAC-1, RAC-2, RE-1, IE-1, MR-1, MECH-1
12th May 2019	**N.T.** :	ToM-3, ICE-2
	R.T. :	MR-2, RSE-1, RSE-2, HT-1, HT-2, FMM-2
19th May 2019	**N.T.** :	RE-2, MD-1
	R.T. :	PPE-1, PPE-2, FMM-3, ToM-2, ToM-3
26th May 2019	**N.T.** :	Mech-3, MD-2
	R.T. :	FMM-1, FMM-2, PROD-1, PROD-2, MECH-1, ICE-2, MD-1
02nd Jun 2019	Full Length-1 (Test Paper-1 + Test Paper-2)	
09th Jun 2019	Full Length-2 (Test Paper-1 + Test Paper-2)	
16th Jun 2019	Full Length-3 (Test Paper-1 + Test Paper-2)	

Test Type	Timing
Conventional Test	10:00 A.M. to 1:00 P.M.
Conventional Full Length Test Paper-1	10:00 A.M. to 1:00 P.M.
Conventional Full Length Test Paper-2	02:00 P.M. to 5:00 P.M.

Note : The timing of the test may change on certain dates. Prior information will be given in this regard.

***N.T. :** New Topic. ***R.T. :** Revision Topic

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Subject Code Details

Subject	Code	Topics
Thermodynamic	TH-1	Thermodynamic systems and processes; Zeroth, First and Second Laws of Thermodynamics. properties of pure substance.
	TH-2	Entropy, Irreversibility and availability; Real and Ideal gases; compressibility factor; Gas mixtures.
Heat Transfer	HT-1	Steady and unsteady heat conduction, Fins, Radiative heat transfer.
	HT-2	Free and forced convection, boiling and condensation, Heat exchanger.
IC Engines	ICE-1	SI and CI Engines, Engine Systems and Components, Fuels.
	ICE-2	Performance characteristics and testing of IC Engines; Emissions and Emission Control. Otto, Diesel and Dual Cycles.
Refrigeration Air Conditioning	RAC-1	Vapour compression refrigeration, Refrigerants, Compressors, Other types of refrigeration systems like Vapour Absorption, Vapour jet, thermo electric and Vortex tube refrigeration and Heat pump.
	RAC-2	Psychometric properties and processes, Comfort chart, Comfort and industrial air conditioning, Load calculations and Condensers, Evaporators and Expansion devices.
Fluid Mechanics and Machinery	FMM-1	Basic Concepts and Properties of Fluids, Manometry, Fluid Statics, Buoyancy, Equations of Motion such as velocity potential, Stream Function.
	FMM-2	Bernoulli's equation and applications, Viscous flow of incompressible fluids, Laminar and Turbulent flows, Flow through pipes and head losses in pipes.
	FMM-3	Reciprocating and Centrifugal pumps, Hydraulic Turbines and other hydraulic machines.
Power Plant Engineering	PPE-1	Steam and Gas Turbines, Rankine and Brayton cycles with regeneration and reheat.
	PPE-2	Fuels and their properties, Flue gas analysis, Theory of Jet Propulsion – Pulse jet and Ram Jet Engines, Reciprocating and Rotary Compressors.
	PPE-3	Boilers, power plant components like condensers, air ejectors, Electrostatic precipitators and cooling towers.
Renewable Sources of Energy	RSE-1	Solar Radiation, Solar Thermal Energy collection - Flat Plate andfocusing collectors their materials and performance. Solar Thermal Energy Storage, Applications – heating, cooling and Power Generation.
	RSE-2	Solar Photovoltaic Conversion; Harnessing of Wind Energy, Bio-mass and Tidal Energy – Methods and Applications, Working principles of Fuel Cells.
Engineering Mechanics (SoM)	Mech-1	Analysis of System of Forces, Friction, Centroid and Centre of Gravity, Dynamics.
	Mech-2	Stresses and Strains-Compound Stresses and Strains, Bending Moment and Shear Force Diagrams.
	Mech-3	Theory of Bending Stresses-Slope and deflection-Torsion, Thin and thick Cylinders, Spheres.
Engineering Materials	MS-1	Basic Crystallography, Alloys and Phase diagrams, Heat Treatment.
	MS-2	Ferrous and Non Ferrous Metals, Non metallic materials, Basics of Nano-materials, Mechanical Properties and Testing, Corrosion prevention and control.
Mechanisms and Machines	ToM-1	Mechanisms, Kinematic Analysis, Velocity and Acceleration. CAMs with uniform acceleration, cycloidal motion, oscillatingfollowers; Effect of Gyroscopiccouple on automobiles, ships and aircrafts. Governors.
	ToM-2	Vibrations –Free and forced vibration of undamped and damped SDOF systems, Transmissibility Ratio, Vibration Isolation, Critical Speed of Shafts.
	ToM-3	Geometry of tooth profiles, Law of gearing, Interference, Helical, Spiral and Worm Gears, Gear Trains- Simple, compound and Epicyclic. Slider crank mechanisms, Balancing.
Design of Machine Elements	MD-1	Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as riveted, welded and bolted joints.
	MD-2	Shafts, Spur gears, rolling and sliding contact bearings, Brakes and clutches, flywheels.
Manufacturing, Industrial and Maintenance Engineering	PROD-1	Metal casting-Metal forming, Metal Joining, computer Integrated manufacturing, FMS.
	IE-1	Production planning and Control, Inventory control
	RE-1	Failure concepts and characteristics- Reliability, Failure analysis, Machine Vibration, Data acquisition, Fault Detection, Vibration Monitoring.
	PROD-2	Machining and machine tool operations, Limits, fits and tolerances, Metrology and inspection.
	IE-2	Operations research - CPM-PERT
	RE-2	Field Balancing of Rotors, Noise Monitoring, Wear and Debris Analysis, Signature Analysis, NDT Techniques in Condition Monitoring.
Mechatronics and Robotics	MR-1	Microprocessors and Micro controllers: Architecture, programming, I/O,Computer interfacing, Programmable logic controller. Sensors and actuators, Piezoelectric accelerometer, Hall effect sensor, Optical Encoder, Resolver, Inductosyn, Pneumatic and Hydraulic actuators, stepper motor, Control Systems- Mathematical modeling of Physicalsystems, control signals, controllability and observability
	MR-2	Robotics, Robot Classification, Robot Specification, notation; Direct and Inverse Kinematics; Homogeneous Coordinates and Arm Equation of four Axis SCARA Robot.

pipe of constant cross-section is 4.36 and 3.66 respectively. Hence,

$$(Nu)_q > (Nu)_T$$

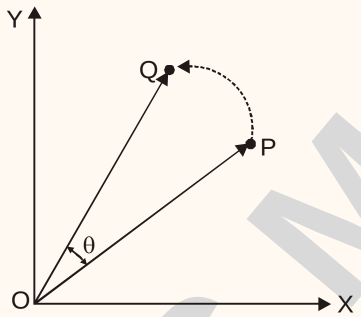
26. In a casting process, a vertical channel through which molten metal flows downward from pouring basin to runner for reaching the model cultivate is called

(a) riser (b) blister

(c) pin hole (d) sprue

Ans. (d)

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



(a) (12.32, 18.66) (b) (18.66, 12.32)

(c) (22.32 ,8.26) (d) (13.40, 22.32)

Ans. (a)

Sol. $^1P = {}^2T_1\ {}^2P$, rotates anticlockwise

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos 30 & -\sin 30 \\ \sin 30 & \cos 30 \end{bmatrix} \begin{bmatrix} 20 \\ 10 \end{bmatrix}$$

$$= \begin{bmatrix} 0.866 & -0.5 \\ 0.5 & 0.866 \end{bmatrix} \begin{bmatrix} 20 \\ 10 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 0.866 \times 20 - 0.5 \times 10 \\ 0.5 \times 20 + 0.866 \times 10 \end{bmatrix}$$

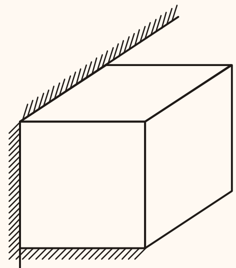
$$= \begin{bmatrix} 12.32 \\ 18.66 \end{bmatrix}$$

$$(x', y') = (12.32,\ 18.66)$$

28. 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. (60)

Sol.



$$a = 1 \text{ m}$$

$$T_a = 32°C, \quad \alpha = 1\times10^{-5} / °C$$

$$K = 200 \text{ GPa}$$

$$\Delta T = 10°C$$

$$\epsilon_v = \frac{(1-2\mu)}{E}(3\sigma) = 3\alpha T$$

As $\sigma_1 = \sigma_2 = \sigma_3 = \sigma$

(mean volumetric stress)

$$\sigma\frac{(1-2\mu)}{E} = \alpha\Delta T \qquad E = 3K(1-2\mu)$$

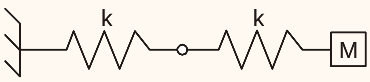
$$\sigma = \frac{E\alpha\Delta T}{1-2\mu} \qquad \frac{E}{1-2\mu} = 3K$$

$$\sigma = 3K\alpha\Delta T$$

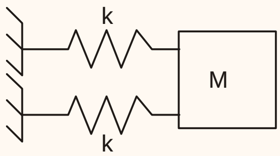
$$= 3 \times 200 \times 10^3 \times 1 \times 10^{-5} \times 10$$

$$\sigma = 60 \text{ MPa}$$

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



System I



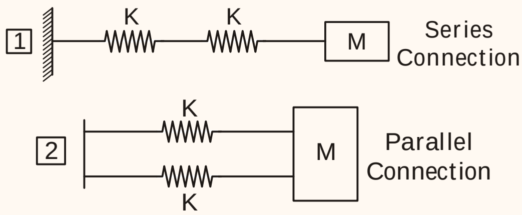
System II

(a) 4 (b) 2

(c) $\frac{1}{4}$ (d) $\frac{1}{2}$

Ans. (d)

Sol.



$$\frac{1}{\{K_{eq}\}} = \frac{1}{K_1} + \frac{1}{K_2}$$

$$\Rightarrow \left(K_{eq_1} = \frac{K_1 K_2}{K_1 + K_2}\right) = \frac{K}{2}$$

$$(K_{eq})_2 = K_1 + K_2 = 2\text{ K}$$

Natural frequency $\left(\omega = \sqrt{\frac{K}{m}}\right)$

$$\frac{\omega_1}{\omega_2} = \frac{\sqrt{\frac{K}{2m}}}{\sqrt{\frac{2K}{m}}} = \frac{1}{2}$$

30. The lengths of a large stock of titanium rods follow a normal distribution with a mean (μ) of 440 mm and a standard deviation (σ) of 1 mm. What is the percentage of rods whose lengths lie between 438 mm and 441 mm ?

(a) 68.4% (b) 99.75%

(c) 81.85% (d) 86.64%

Ans. (c)

Sol.

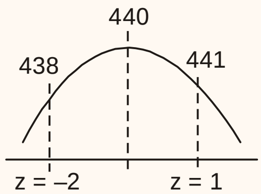
$$u = 440 \text{ mm}$$

$$\sigma = 1\text{mm}$$

$$Z = \frac{X - u}{\sigma}$$

lower limit,

$$Z(x = 438) = \frac{438 - 440}{1} = -2$$



$$Z(x = 441 \text{ mm}) = \frac{441 - 440}{1} = 1$$

Percentage of rods whose lengths lie between 438 mm and 441 mm.

$$= 0.3413 + (0.5 - 0.0228)$$

$$= 0.81854 = 81.854\%$$

31. 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. (0.66)

Sol.

$$\begin{aligned} \text{Air,} \quad m &= 1 \text{ kg} \\ T &= 300\text{K} \xrightarrow{\text{Isothermally}} T = 300\text{K},\ P_2 = 1\text{bar} \\ P_1 &= 10 \text{ bar} \\ R &= 0.287 \text{ kJ/kg k} \end{aligned}$$

$$\begin{aligned} \Delta s &= mc_p \ell n \cancel{\left(\frac{T_2}{T_1}\right)} - mR\ell n\left(\frac{P_2}{P_1}\right) \\ &= -1 \times 0.287 \ell n\left(\frac{1}{10}\right) \\ &= 0.66 \text{ kJ/kg k} \end{aligned}$$

32. Which one of the following welding methods provides the highest heat flux (W/mm²) ?

(a) Tungsten inert gas welding

(b) Laser beam welding

(c) Oxyacetylene gas welding

(d) Plasma arc welding

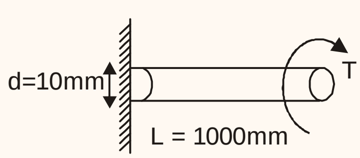
Ans. (b)

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

Ans. (0.87)

Sol.

$$\theta = 10°$$



Torsion equation

$$\frac{T}{J} = \frac{T_{max}}{R_0 \text{ or } R} = \frac{G\theta}{L}$$

$$\begin{aligned} \frac{T_{max}}{G} &= \gamma_{max} = \frac{R\theta}{L} = \frac{5 \times 10 \times \frac{\pi}{180}}{1000} \\ &= 0.87 \times 10^{-3} \end{aligned}$$

$$\boxed{p = 0.87}$$

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

Ans. (63)

Sol.

Trapezoidal Rule, h = 1

$$\begin{aligned} \int ydx &= \frac{h}{2}\left[(y_0 + y_1) + 2(y_1 + y_2 + \ldots\ldots)\right] \\ &= \frac{1}{2}\left[(2^3 + 4^3) + 2(3^3)\right] \\ &= \frac{1}{2}[8 + 64 + 54] = 63 \end{aligned}$$

35. During a non-flow thermodynamic process (1-2) executed by a perfect gas, the heat interaction is equal to the work interaction ($Q_{1-2} = W_{12}$) when the process is

(a) Adiabatic (b) Polytropic

(c) Isothermal (d) Isentropic

Ans. (c)

Sol.

For isothermal process

$$\delta u = 0$$

As per Ist law of thermodynamics

$$\delta\theta = \cancel{\delta u} + \delta w$$

$$\boxed{\delta\theta = \delta w}$$

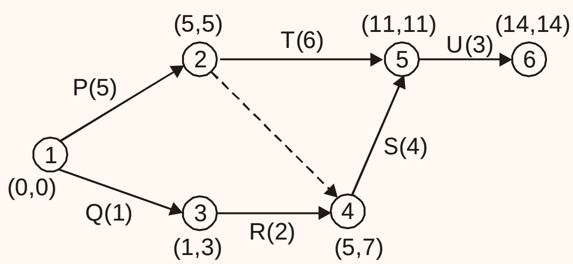
36. A project consists of six activities. The immediate predecessor of each activity and the estimated duration is also provided in the table below :

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. (6)

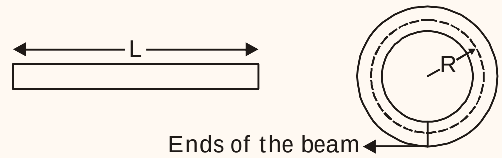
Sol.



$$\text{Total float} = L_j - E_i - t_{ij}$$
$$= 11 - 5 - 4 = 2$$

Maximum duration of activity S, without delaying the completion of project = Total float + activity time = 2 + 4 = 6

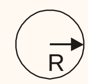
37. Consider an elastic straight beam of length $L = 10\pi$ m, with square cross-section of side a = 5 mm, and Young's modulus E = 200 GPa. This straight beam was bent in such a way that the two ends meet, to form a circle of mean radius R. Assuming that Euller-Bernoulli beam theory is applicable to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



Ans. (100)

Sol.

$$\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R}$$



$L = 2\pi R$
$10\pi = 2\pi R$
$R = 5$

$$\sigma = \frac{Ey}{R}$$
$$= \frac{200\times10^3\times2.5\times10^{-3}}{5}$$
$$= 100 \text{ Mpa}$$

38. 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 0.1 mm/rev. The center line average surface roughness (in μm, round off to one decimal place) of the generated surface is _____.

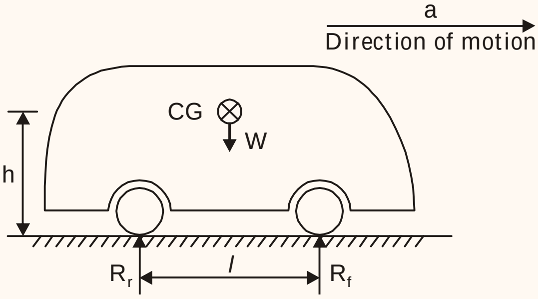
Ans. (3.7)

Sol.

$$R_a = \frac{f}{4(\tan C_s + \cot C_E)}$$
$$= \frac{0.1}{4(\tan 45 + \cot 10)}$$
$$= 3.7 \times 10^{-3} \text{ mm}$$
$$\boxed{R_a = 3.7\mu m}$$

39. 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 reaction on the front wheels (R_f) and rear wheels (R_r)

are given by :



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

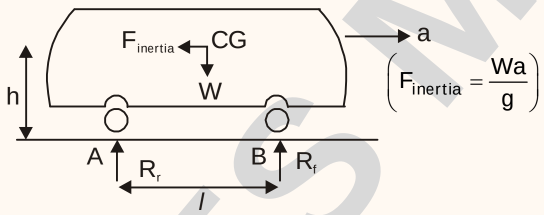
(b) $R_f = R_r = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$

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

(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. (a)

Sol.



$$\sum M_A = 0,\ F_{inertia} \times h + R_f \times \ell - W \times \frac{\ell}{2} = 0$$

$$R_f = \frac{\frac{W\ell}{2} - h \times \frac{w_a}{g}}{\ell}$$

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

$$\sum f_y = 0 \quad W = R_f + R_r$$

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

40. 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. (40)

Sol.

$$VT^n = c$$

for Tool X, $VT^{0.3} = 60$

for Tool y, $VT^{0.6} = 90$

Velocity when both tools have same tool life.

$$\frac{T^{0.3}}{T^{0.6}} = \frac{60}{90}$$

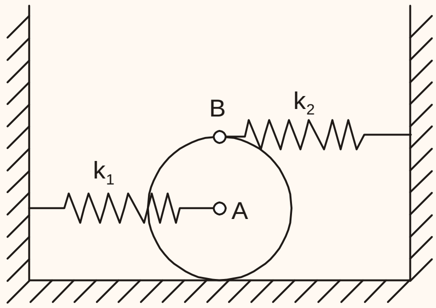
$$(T)^{0.3-0.6} = \frac{6}{9}$$

$$T^{0.3} = 1.5$$

$$T = (1.5)^{1/0.3} \text{ min}$$

$$V = \frac{60}{(1.5)^{0.3/0.3}} = 40 \text{ m/min.}$$

41. A uniform thin disk of mass 1 kg and radius 0.1 m is kept on a surface as shown in the figure. The spring of stiffness k_1 = 400 N/m is connected to the disk center A and another spring of stiffness k_2 = 100 N/m is connected at point B just above point A on the circumference of the disk. Initially, both the springs are unstretched. A 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).

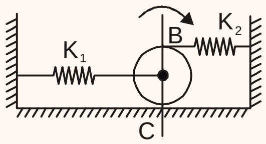


Ans. **(23.1)**

Sol.

$$m = 1 \text{ kg}, R = 0.1\text{m}$$

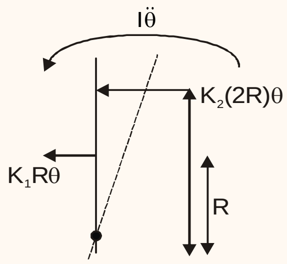
$$K_1 = 400 \text{ N/m}, K_2 = 100 \text{ N/m}$$



Assme pure rolling of the disc

$$M_c = 0 \text{ at I.C. at point (C)}$$

$$I_c\ddot{\theta} + K_2(2R)\theta \times 2R + K_1R\theta \times R = 0$$



$$I_c = I_{disc} + mR^2$$

$$= \frac{mR^2}{2} + mR^2$$

$$= \frac{3}{2}mR^2 = \frac{3}{2} \times 0.1^2 = 1.5 \times 10^{-2}$$

$$1.5 \times 10^{-2}\ddot{\theta} + 4 \times 100 \times 0.1^2\theta + 400 \times 0.1^2\theta = 0$$

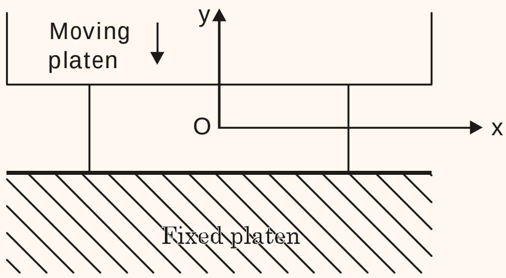
$$1.5 \times 10^{-2}\ddot{\theta} + 800 \times 0.1^2\theta = 0$$

$$\omega_n = \sqrt{\frac{800 \times \cancel{0.1^2}}{1.5 \times \cancel{0.1^2}}}$$

$$\omega_n = 23.094 \text{ rad/s}$$

$$\omega_n = 23.1$$

42. 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 300 MPa 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) 260 MPa (compressive)

(b) 260 MPa (tensile)

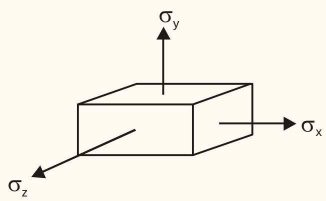
(c) 340 MPa (tensile)

(d) 340 MPa (compressive)

Ans. **(d)**

Sol. Plain strain compression (Forging)

σ_x, σ_y & σ_z are pricipal stress



under plane strain condition, $\epsilon_z = 0$

$$\Rightarrow \frac{\sigma_z}{E} - \frac{\mu\sigma_y}{E} - \frac{\mu\sigma_x}{E} = 0$$

$$\Rightarrow \sigma_z = \mu(\sigma_x + \sigma_y)$$

but $\sigma_x = -40$

$$\Rightarrow \sigma_z = \mu(-40+\sigma_y)$$

Assuming, $(\mu = 0.5)$ at yielding condition.

$$\sigma_z = 0.5(-40+\sigma_y), \sigma_y, \sigma_x = -40$$

As per Tresca (Maximum shear stress) criterion.

$$\frac{S_{yt}}{2} = \max\left[\left|\frac{\sigma_x-\sigma_y}{2}\right|, \left|\frac{\sigma_y-\sigma_z}{2}\right|, \left|\frac{\sigma_z-\sigma_x}{2}\right|\right]$$

$$\Rightarrow \frac{300}{2} = \left[\frac{|40+\sigma_y|}{2}, \frac{|0.5\sigma_y+20|}{2}, \frac{|0.5\sigma_y+20|}{2}\right]$$

$$\frac{0.5\sigma_y+20}{2} = \pm\frac{300}{2}$$

$$\sigma_y = +560 \text{ MPa}, -640 \text{ MPa}$$

$$\frac{\sigma_y+40}{2} = \pm\frac{300}{2}$$

$$\sigma_y = +260 \text{ MPa}, -340 \text{ MPa}$$

As block is under compression in y-direction,

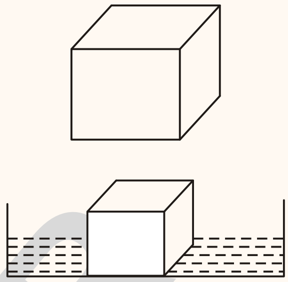
hence, 340 Mpa compression is the correct option.

43. A cube of side 100 mm is placed at the bottom of an empty container on one of its faces. The density of the material of the cube is 800 kg/m^3. Liquid of density 1000 kg/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. (80)

Sol.

a = 100mm



Minimum height to which the liquid needs to be poured into the container for the cube to just lift up, hence

$$F_B \geq (mg)_{block}$$

$$\rho_f g V_{fd} \geq (\rho V)_{block} \times g$$

$$1000 \times 0.1 \times 0.1 \times h \geq 800 \times 0.1 \times 0.1 \times 0.1$$

$$h \geq 0.08\text{m}$$

$$h \geq 80\text{mm}$$

44. In a UTM experiment, a sample of length 100 mm, was loaded in tension until failure. The failure load was 40 kN. The displacement, measured using the cross-head motion, at failure, was 15 mm. 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. (2)

Sol. Compliance is the ratio of load point deflection and applied load.

$$\text{UTM constant} = \frac{\Delta L}{P} = C$$

$$\text{As per Hooke's law, } \frac{\sigma}{\epsilon} = E$$

$$\text{or, } \frac{\frac{P}{A}}{\frac{\Delta L}{L}} = E$$

$$\Rightarrow \quad \frac{PL}{A\Delta L} = E$$

$$\text{or,} \quad \frac{\Delta L}{P} = \frac{L}{AE} = \text{UTM constant} = C$$

Now, L = 100 mm, ΔL = 15 mm,

C = 5 × 10^{-8} m/N, P = 40 kN

$$\text{Strain} = \frac{\Delta L}{L} = \frac{P}{AE} = \frac{P}{L/C}$$

$$= \frac{PC}{L} = \frac{40\times10^{3}\times5\times10^{-8}}{100\times10^{-3}} = 2\times10^{-2}$$

$\therefore$ Strain in % = 2 × 10^{-2} × 100% = 2%

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

(a) 875 MPa (b) 200 MPa

(c) 722 MPa (d) 920 MPa

Ans. (c)

Sol.

$$N = 1000 \text{ rpm}, \ \alpha = 10$$

$$f = 100 \text{ mm/min}$$

$$= \frac{100}{1000}\frac{\text{mm}}{\text{rev}}$$

$$f = 0.1\frac{\text{mm}}{\text{rev}} = t$$

$$r = \frac{t}{t_c} = \frac{0.1}{0.3} = \frac{1}{3}$$

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

$$\Rightarrow \quad \tau_s = \frac{F_s \sin\phi}{6\times t}$$

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

$$\Rightarrow \quad \phi = 19.19°$$

$$F_s = F_c\cos\phi - F_t\sin\phi$$

$$= 1601\times\cos19.19° - 1259\sin19.19$$

$$= 1098.20 \text{ N}$$

$$\tau_s = \frac{1098.20\times\sin19.19°}{5\times0.1}$$

$$= 721.96$$

$$\approx 722 \text{ Mpa}$$

46. The rotor of turbojet engine of an aircraft has a mass 180 kg and polar moment of inertia 10 kg.m^2 about the rotor axis. The rotor rotates at a constant speed of 1100 rad/s in the clockwise direction when viewed from the front of the aircraft. The aircraft while flying at a speed of 800 km per hour takes a turn with a radius of 1.5 km 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) 1629.6 N.m and the nose goes up

(b) 162.9 N.m and the nose goes up

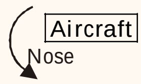
(c) 162.9 N.m and the nose goes down

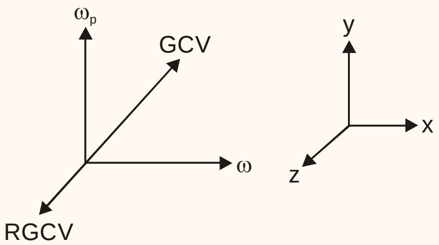
(d) 1629.6 N.m and the nose goes down

Ans. (d)

Sol.

$$G = I\omega\omega_p$$

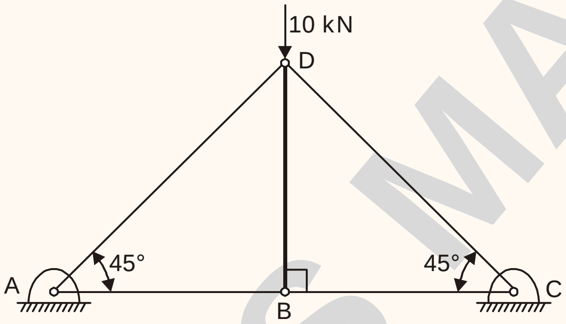




Effect $\Rightarrow$ Nose goes down

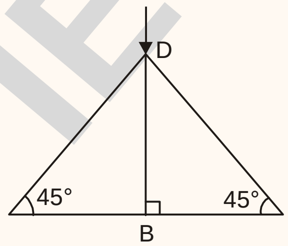
$$G = 10 \times 1100 \times \frac{800 \times 5}{1800 \times 18}$$
$$= 1629.63 \text{ Nm}$$
$$G = 1629.63 \text{ N.m}$$

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

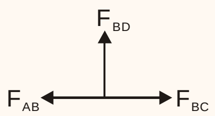


Ans. (5)

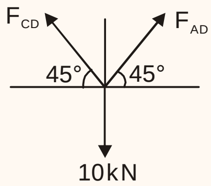
Sol.



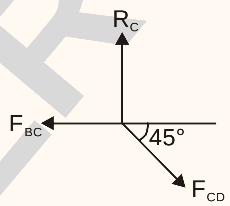
$$F_{BD} = 0$$



At joint D,

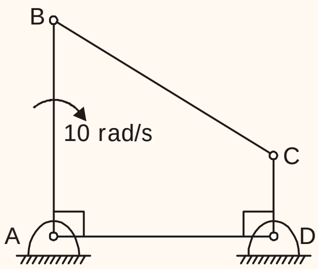


At joint C,



$$\sum Fx = 0$$
$$F_{CD}\cos 45 = F_{AD}\cos 45$$
$$F_{CD} = F_{AD}$$
$$\sum Fy = 0, 10 = 2F_{CD}\sin 45$$
$$F_{CD} = \frac{10}{\sqrt{2}} \text{ kN}$$
$$F_{CD}\cos 45 = F_{BC}$$
$$F_{BC} = \frac{10}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = 5\text{kN}$$

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



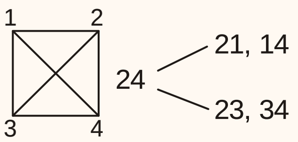
(a) 0 (b) 25

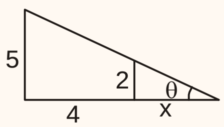
(c) 10 (d) 15

Ans. **(b)**

Sol.

$$AB = 4cm$$
$$AD = 4cm$$
$$CD = 2cm$$
$$\omega_{AB} = 10 \text{ rad/s}$$
$$\omega_2 \left(I_{24} I_{12}\right) = \omega_4 \left(I_{24} I_{14}\right)$$





$$\frac{2}{x} = \frac{5}{4+x}$$
$$8 + 2x = 5x$$
$$8 = 3x$$
$$x = \frac{8}{3}$$

$$10(x + 4) = \omega \times x$$
$$10\left(\frac{8}{3} + 4\right) = \omega \times \frac{8}{3}$$
$$10 \times \frac{20}{3} \times \frac{3}{8} = \omega$$
$$\omega = \frac{200}{8} = 25 \text{ rad/s}$$

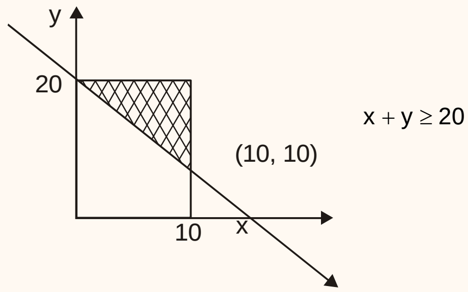
49. The variable x takes a value between 0 and 10 with uniform probability distribution. The variable y takes a value between 0 and 20 with uniform probability distribution. The probability of the sum of variables (x + y) being greater than 20 is

(a) 0.33 (b) 0.25

(c) 0 (d) 0.50

Ans. **(b)**

Sol.

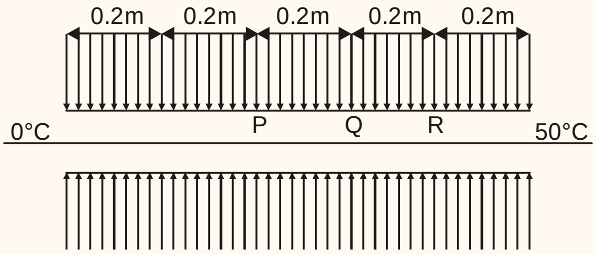


$$\text{Probability } (x + y > 20) = \frac{\frac{1}{2} \times 10 \times 10}{20 \times 10}$$

$$= \frac{1}{4} = 0.25$$

50. The wall of a constant diameter pipe of length 1 m is heated uniformly with flux q" 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 temperatures are 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



Constant wall flux

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

(a) R only (b) P and Q only

(c) P, Q and R (d) Q and R only

Ans. (d)

Sol. In case of uniform heat flux, bulk mean temperature varies linearly. The difference between bulk mean temperature and wall temperature is constant in thermally developed region so bulk tempeature

$$T(x) = A + Bx$$

At $x = 0,\ T = 0°C$

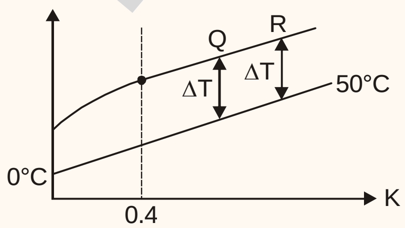
$\Rightarrow$ $A = 0°C$

At $x = 1,\ T = 50°C$

$\Rightarrow$ $B = 50°C$

$\therefore$ $T(x) = 50x$

Location	Wall temp. (T_w)	bulk temp. $T(x)$	$\Delta T = T_w - T(x)$
P, $x = 0.4$	50°C	20°C	30°C
Q, $x = 0.6$	80°C	30°C	50°C
R, $x = 0.8$	90°C	40°C	50°C



So, Q and R in thermally developed region.

51. 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) $4y^2 - 4xy + \text{constant}$

(b) $4xy - 2x^2 + 2y^2 + \text{constant}$

(c) $2x^2 - 2y^2 + xy + \text{constant}$

(d) $-4xy + 2y^2 - 2x^2 + \text{constant}$

Ans. (b)

Sol. $u(x,y) = 2x^2 - 2y^2 + 4xy$

As harmonic function is analytic

$$u_x = V_y$$

$$u_y = -V_x$$

$$u_x = 4x + 4y$$

$$u_y = -4y + 4x$$

$$\frac{\partial v}{\partial y} = V_y = 4x + 4y$$

$$V = 4xy + 2y^2 + f(x)$$

$$\frac{\partial v}{\partial x} = 4y + f'(x) = 4y - 4x$$

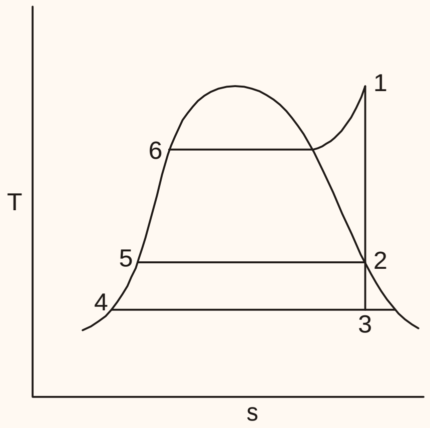
$$f'(x) = -4x$$

$$f(x) = -2x^2 + C$$

$$V = 2y^2 - 2x^2 + 4xy + C$$

52. A steam power cycle with regeneration as shown below on the T-s diagram employs a single open feedwater heater for efficiency improvement. The fluids mix with each other in an open feedwater heater. The turbine is isentropic and the input (bleed) to the feedwater 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 boilder 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. (20)

Sol.

$$xh_2 + (1-x)h_4 = h_5$$

$$x \times 2800 + (1-x) \times 175 = 700$$

$$x = 0.2$$

20% of mass flow rate of steam bled from the turbine of total mass flow rate.

53. If one mole of H_2 gas occupies a rigid container with a capacity of 1000 liters 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 = 8.314 J/mol.K).

Ans. (83.14)

Sol.

$n = 1$, H_2 gas (Rigid container)

$V = 1000\ \text{lt} = 1\text{m}^3$ $\quad V_1 = V_2$

$T_1 = 27°C$ $\quad R = 8.314\ \text{J/mol k}$

$T_2 = 37°C$

Change in pressure, $(P_2 - P_1)$ Pa

$$PV = nRT$$

$$P_1V_1 = nRT_1$$

$$P_1 = \frac{nRT_1}{V_1}$$

$$\Delta P = \frac{nRT_2}{V_2} - \frac{nRT_1}{V_1}$$

$$= \frac{nR}{V}\left[T_2 - T_1\right]$$

$$= \frac{1 \times 8.314}{1} \times 10$$

$$\Delta P = 83.14\ \text{Pa}$$

54. A circular shaft having diameter $65.00^{+0.01}_{-0.05}$ mm is manufactured by turning process. A $50\mu m$ thick coating of TiN is deposited on the shaft Allowed variation in TiN film thickness is $\pm 5\mu m$. The minimum hole diameter (in mm) to just provide clearance fit is

(a) 65.01 (b) 64.95

(c) 65.12 (d) 65.10

Ans. (c)

Sol.

$50\mu m$ thick coating

$$\text{Shaft} = 65^{+0.01}_{-0.05}\text{mm}$$

$$t = (50 \pm 5)\mu m$$

To proivde clearnace

$$(D_H)_{min} \ge \left((D)_{shaft}\right)_{max}$$

$$\ge (D_s)_{max} + 2t_{max}$$

$$= 65.01 + \frac{2 \times 55}{1000} = 65.12\text{mm}$$

55. The set of equations

$$x + y + z = 1$$
$$a - ay + 3z = 5$$
$$5x - 3y + az = 6$$

has infinite solution, if a =

(a) –4 (b) 3
(c) 4 (d) –3

Ans. (c)

Sol.

$$\rho(A) = \rho(AB) < \text{no. of variables}$$

$$|A| = 0$$

$$\begin{vmatrix} 1 & 1 & 1 \\ a & -a & 3 \\ 5 & -3 & a \end{vmatrix} = 0$$

$(-a^2 + 9) - (a^2 - 15) + (-3a + 5a) = 0$

$9 - a^2 + 15 - a^2 + 2a = 0$

$2a^2 - 2a - 24 = 0$

$a^2 - a - 12 = 0$

$a^2 - 4a + 3a - 12 = 0$

$(a = 4, -3)$

$$\rho(AB) < (\text{No. of variable})$$

$$\begin{vmatrix} 1 & 1 & 1 \\ -a & 3 & 5 \\ -3 & a & 6 \end{vmatrix} = 0$$

$1(18 - 5a) - 1(-6a + 15) + 1(-a^2 + 9) = 0$

$18 - 5a - 15 + 6a + 9 - a^2 = 0$

$a^2 - a - 12 = 0$

$a = 3, 4 \quad a = 4$

$$\begin{vmatrix} 1 & 1 & 1 \\ a & -a & 5 \\ 5 & -3 & 6 \end{vmatrix} = 0$$

$(-6a + 15) - (6a - 25) + (-3a + 5a) = 0$

$-6a + 15 - 6a + 25 + 2a = 0$

$10a = 40$

$a = 4$

if $a = 4$

$|AB| = 0$

$$\begin{vmatrix} 1 & 1 & 1 \\ a & 3 & 5 \\ 5 & a & 6 \end{vmatrix} = 0$$

$(18 - 5a) - (6a - 25)$

$+(a^2 - 15) = 0$

$a^2 - 11a + 28 = 0$

$a = 7, 4 \quad \boxed{a = 4}$

56. 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 duration 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. (146)

Sol.

	M_1	M_2	M_3	M_4	M_5
J_1	40	30	50	50	58
J_2	26	38	60	26	38
J_3	40	34	28	24	30
J_4	28	40	40	32	48
J_5	28	32	38	22	54

Step-I Substracting each row with min. value of each respective row.

10	0	20	20	28
0	12	34	0	12
16	10	4	0	6
0	12	12	4	20
6	10	16	0	22

Step 2: Substracting each column with min. value of each respectively value.

10	0	16	20	22
0	12	30	0	6
16	10	0	0	0
0	12	8	4	14
6	10	12	0	16

Step-3 Assigning row and column

10	$\boxed{0}$	16	20	22
$\cancel{0}$	12	30	$\cancel{0}$	6
16	10	$\boxed{0}$	$\cancel{0}$	$\cancel{0}$
$\boxed{0}$	12	8	4	14
6	10	12	$\boxed{0}$	16

Step-4

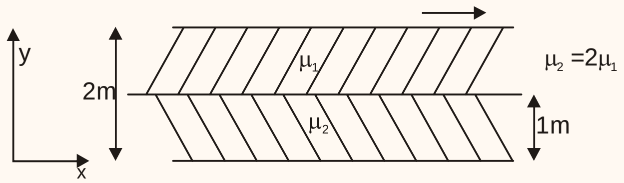
16	$\boxed{0}$	16	26	22
$\cancel{0}$	6	24	$\cancel{0}$	$\boxed{0}$
22	10	$\boxed{0}$	6	$\cancel{0}$
$\boxed{0}$	6	2	4	8
6	4	6	$\boxed{0}$	10

Step-5 Min. time = 28 + 30 + 28 + 22 + 38 = 146 min

57. Two immiscible, incompressible, viscous fluids having same densities but different viscosities are contained between two infinite horizontal parallel plates. 2 m apart as shown below. The bottom plate is fixed and the upper plate moves to the right with a constant velocity of 3 m/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

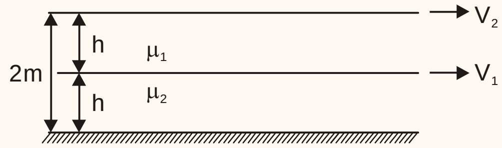
$$\frac{d^2u}{dy^2} = 0$$

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



Ans. **(1)**

Sol.



$$\mu_2 = 2\mu_1$$

$$V_2 = 3 \text{ m/s}$$

Shear stress value at intermediate plate will be

$$\tau = \frac{\mu_2 V_1}{h} = \frac{\mu_1 (V_2 - V_1)}{h}$$

$$2 V_1 = V_2 - V_1$$

$$V_2 = 3 V_1 \quad V_2 = 3 \text{ m/s}$$

$$V_1 = 1 \text{ m/s}$$

58. 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 468 MPa. The factor of safety on the basis of maximum shear stress theory is _____ (round off to one decimal place).

Ans. **(1.8)**

Sol. $\sigma_x = 100$ MPa

$$\sigma_y = 220 \text{ MPa}$$

$$\tau_{xy} = 80 \text{ MPa}$$

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

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

$$= 160 \pm \sqrt{55^2 + 80^2}$$

$$\sigma_{1,2} = 160 \pm 97.0824$$

$$\Rightarrow \quad \sigma_1 = 257.08 \text{ Mpa}, \ \sigma_2 = 62.9 \text{ MPa}$$

As per maximum shear stress theory

$$\frac{S_{yt}}{2N} = \text{Max}\left[\left|\frac{\sigma_1 - \sigma_2}{2}\right|, \frac{\sigma_1}{2}, \frac{\sigma_2}{2}\right]$$

$$\frac{S_{yt}}{2N} = \frac{\sigma_1}{2} = \frac{257.08}{2}$$

$$N = \frac{468}{257.08} = 1.8$$

59. Match the following sand mold casting effects with their respective causes.

	Defect		Cause
P	Blow hole	1.	Poor Collapsibility
Q	Misrum	2.	Mold erosion
R	Hot tearing	3.	Poor permeability
S	Wash	4.	Insufficient fludity

(a) P-3, Q-4, R-1, S-2

(b) P-3, Q-4, R-2, S-1

(c) P-4, Q-3, R-1, S-2

(d) P-2, Q-4, R-1, S-3

Ans. (a)

60. A gas is heated in a duct as it flows over a resistance heater. Consider a 101 kW electric heating system. The gas enters the heating section of the duct at 100 kPa and 27°C with a volume flow rate of 15 m³/s. If heat is lost from the gas in the duct to the surroundings at a rate of 51 kW, the exit temperature of the gas is

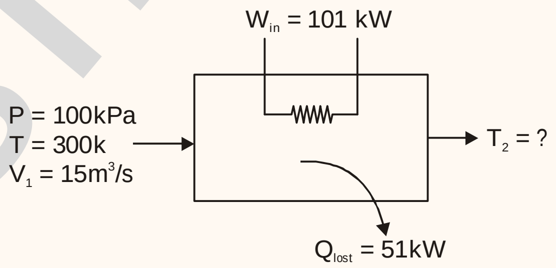
(Assume constant pressure, ideal gas, negligible change in kinetic and potential energies and constant specific heat : C_p =1 kJ/kg.K; R = 0.5 kJ/kg K).

(a) 37°C (b) 76°C

(c) 53°C (d) 32°C

Ans. (d)

Sol.



$$C_p = 1 \frac{\text{kJ}}{\text{kgK}}$$

$$R = 0.5 \frac{\text{kJ}}{\text{kgK}}$$

$$\dot{m} = \frac{P_1 \dot{V}_1}{R T_1} = \frac{100 \times 15}{0.5 \times 300} = 10 \frac{\text{kg}}{\text{s}}$$

Applying steady flow energy equation,

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

$$10 \times 1 \times 300 + (-51) = 10 \times 1 \times T_2 + (-101)$$

$$T_2 = 305 \text{ K} = 32°\text{C}$$

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

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

Ans. (2.097)

Sol.

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

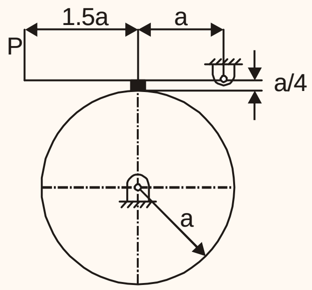
$$= \frac{\ln x^2}{2} - \int \left[\frac{1}{x} \times \frac{x^2}{2}\right] dx$$

$$= \left.\frac{x^2 \ln x}{2} - \frac{x^2}{4}\right|_1^e$$

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

$$= \frac{e^2+1}{4} = 2.097$$

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



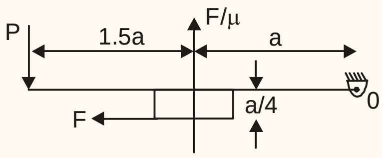
Ans. (212.5)

Sol.

$$T = 250 \text{ Nm}$$

$$F \times r = 250$$

$$F = \frac{250}{a}$$



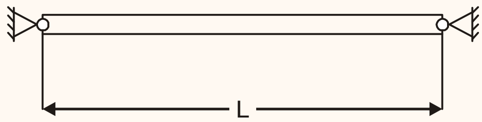
$$\sum M_0 = 0$$

$$P \times 2.5a = F \times \frac{a}{4} + \frac{F}{\mu} \times a$$

$$2000 \times 2.5a = \frac{250 \times a}{a \times 0.25} + \frac{250}{a} \times \frac{a}{4}$$

$$a = \frac{1000 + 62.5}{5000} = 212.5\text{mm}$$

63. 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 = 6 mm. The Young's modulus E = 20 GPa, and the coefficient of thermal expansion $\alpha = 3 \times 10^{-6}\,K^{-1}$. The minimum temperature rise required to cause Euler buckling of the beam is _____ K.



Ans. (1)

Sol.

$$L = \pi m$$

$$P_{th} = P_{axial}$$

$$\alpha TEA = \frac{\pi^2 EI}{L^2}$$

$$3 \times 10^{-6} \times \Delta T \times 6 \times 6 \times 10^{-6} = \frac{\pi^2 \times \frac{1}{12} \times \left(6 \times 10^{-3}\right)^4}{\pi^2}$$

$$\Delta T = 1K$$

64. A gas turbine with air as the working fluid has an isentropic efficiency of 0.70 when operating at a pressure ratio of 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. (0.51)

Sol.

$$\eta = 0.7, (r_p)_1 = 3$$

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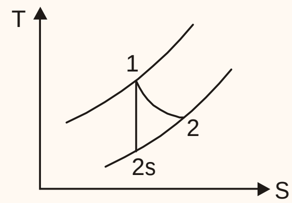
$$\eta_2 = ? \quad (r_p)_2 = 5$$

$$r = 1.4$$

$$(W_T)_1 = (W_T)_2$$

Inlet condition same,



$$\eta_1 = \frac{h_1 - h_2}{h_1 - h_{2s}}$$

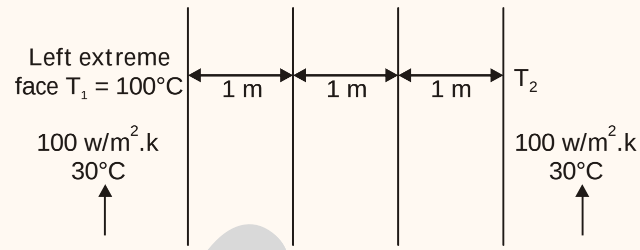
$$= \frac{T_1 - T_2}{T_1 - T_{2s}} = \frac{T_1 - T_2}{T_1 - \frac{T_1}{x}}$$

$$\eta_1\left(T_1 - \frac{T_1}{x}\right) = \eta_2\left(T_1 - \frac{T_2}{y}\right)$$

$$0.7\left(1 - \frac{1}{(3)^{2/7}}\right) = 0.7\left(1 - \frac{1}{(5)^{2/4}}\right)$$

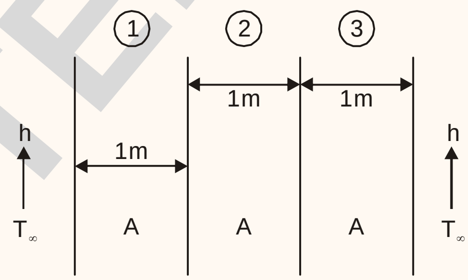
$$\boxed{\eta = 0.51}$$

65. Three slabs are joined together as shown in the figure. There is no thermal contact resistance at the interfaces. The center slab experience a nonuniform internal heat generation with an average value equal to 10000 Wm^{-3}, while the left and right slabs have no internal heat generation. All slabs have thickness equal to 1 m and thermal conductivity of each slab is equal to 5 Wm^{-1} K^{-1}. The two extreme faces are exposed to fluid with heat transfer coefficient 100 $Wm^{-2}K^{-1}$ 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 T1 is measured to be 100°C, the right extreme faced temperature T_2 is _____ °C.



Ans. (60)

Sol.



$A = 1m^2$

Heat generated in the slab (2) will be convected away from the slabs 1 and 3

$$\text{i.e.} \quad \dot{E}_{gen} = \dot{Q}_{1,conv} + \dot{Q}_{3,conv}$$

$$\dot{Q}_{1,conv} = h \times A \times (T_1 - T_\infty)$$

$$= 100 \times 1 \times (100 - 30)$$

$$= 7000 \text{ W}$$

$$\dot{Q}_{3,conv} = h \times A \times (T_3 - T_\infty)$$

$$Q_{3,conv} = 100 \times 1 \times (T_3 - 30)$$

$$\text{Now} \quad \dot{E}_{gen} = 10{,}000 \times A \times \text{width}$$

$$= 10{,}000 \times 1 \times 1$$

$$\dot{E}_{gen} = 10{,}000 \text{ W}$$

$$\Rightarrow \quad 10{,}000 = 7000 + 100 \times (T_3 - 30)$$

$$\Rightarrow \quad \boxed{T_3 = 60^\circ C}$$