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GATE 2020 MECHANICAL

ENGINEERING GUIDE

with **10 Practice Sets**

(6 in Book & 4 Online Sets)

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INSTRUCTIONS

1. You can access your test on any Window based Desktop, android tablets or ipads and mobile phones absolutely free.
2. Visit the link below or scan the QR code:

4 Mock Tests

http://bit.ly/Gate-Mechanical

3. Click on **"Attempt Free Mock Tests"**, a Registration window pops up, enter all the details in the form & click "Sign UP".
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4 ONLINE PRACTICE SETS

PREFACE

With an aim to provide the best possible material to the students to prepare for the GATE, GATE Masterpiece is a one of its kind for the preparation of Mechanical Engineering Exams and a result of many years of research. Another unique feature of this book is that it has Numerical Answer Type Question which are asked in the GATE Exam.

The key idea, which allows this book to deal with a wide range of content related to the Mechanical Engineering Exams along with covering each and every topic, is based on the syllabus introduced by IIT. Covering 100% topics of the syllabus for Mechanical Engineering Exams, the content of this book includes an extended and thoroughly revised version of a collection of Exhaustive Theory, Past Year Questions, Practice Problems and Mock Tests. It also covers 'Simple MCQs,' and Numerical Answer type Questions in good numbers.

In writing this book, we have assumed that readers are well acquainted with the very basic concepts of Engineering Mechanics, Strength of Materials, Theory of Machines, Fluid Mechanics, Materials, Manufacturing and Industrial Engineering etc. Drafted in compliance with GATE syllabus by qualified and experienced professionals, this book has questions of previous 15 years of GATE examinations. Having 100-150 questions in each chapter with detailed solutions, this book in helpful in practicing and preparing for the exams in an effective manner within the shortest span of time.

Structured approach, Introduction of Concepts in Simple Terms, Fundamental Principles in Context of Simple Application and Accuracy were our main objectives that we aimed while writing this book. In order to make sure that the students get well prepared for the exams, we have divided into three sections.

Students who read this book will gain a basic understanding of principles, problems and solutions, including an introduction to the format of GATE exam.

The book covers all the test areas of the GATE examination, viz.

1. General Aptitude - Covering Verbal Ability and Numerical Ability
2. Engineering Mathematics
3. Technical Section

SUPPLEMENTS: 10 Practice Sets (6 offline + 4 online) designed exactly on the exact pattern of GATE exam.

ABOUT THE AUTHOR

Deepak Pathak is presently working as Assistant Professor in Mechanical Engineering Department at Faculty of Engineering and Technology, Agra College,Agra.He received his B.E (Mechanical Engineering) degree from Hindustan College of Science and Technology, Mathura in 2002 and obtained M.Tech (Production Engineering) from Lingayas University, Faridabad in 2014.He has more than fifteen years of teaching experience.

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Finally, Special thanks go to Disha Publication which has given its best possible effort to prepare such a book, thoroughly checked the solutions, so as to eliminate any possibility of error.

However, some errors may have crept in, so feedbacks from the readers regarding the same are highly appreciated.

Syllabus for Mechanical Engineering (ME)

SECTION I : GENERAL APTITUDE (GA)

Verbal Ability: ______________________________

English grammar, sentence completion, verbal analogies, word groups, instructions, critical reasoning and verbal deduction.

Numerical Ability: ___________________________

Numerical computation, numerical estimation, numerical reasoning and data interpretation.

SECTION II : ENGINEERING MATHEMATICS

Linear Algebra: Matrix Algebra, Systems of linear equations, Eigen values and eigen vectors.

Calculus: Mean value theorems, Theorems of integral calculus, Evaluation of definite and improper integrals, Partial Derivatives, Maxima and minima, Multiple integrals, Fourier series. Vector identities, Directional derivatives, Line, Surface and Volume integrals, Stokes, Gauss and Green's theorems.

Differential equations: First order equation (linear and nonlinear), Higher order linear differential equations with constant coefficients, Method of variation of parameters, Cauchy's and Euler's equations, Initial and boundary value problems, Partial Differential Equations and variable separable method.

Complex variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent' series, Residue theorem, solution integrals.

Probability and Statistics: Sampling theorems, Conditional probability, Mean, median, mode and standard deviation, Random variables, Discrete and continuous distributions, Poisson, Normal and Binomial distribution, Correlation and regression analysis.

Numerical Methods: Solutions of non-linear algebraic equations, single and multi-step methods for differential equations. Transform Theory: Fourier transform, Laplace transform, Z-transform.

SECTION III : TECHNICAL SECTION

Applied Mechanics________________________________

Engineering Mechanics: Free body diagrams and equilibrium; trusses and frames; virtual work; kinematics and dynamics of particles and of rigid bodies in plane motion, including impulse and momentum (linear and angular) and energy formulations; impact.

Strength of Materials: Stress and strain, stress-strain relationship and elastic constants, Mohr's circle for plane stress and plane strain, thin cylinders; shear force and bending moment diagrams; bending and shear stresses; deflection of beams; torsion of circular shafts; Euler's theory of columns; strain energy methods; thermal stresses.

Theory of Machines: Displacement, velocity and acceleration analysis of plane mechanisms; dynamic analysis of slider-crank mechanism; gear trains; flywheels.

Vibrations: Free and forced vibration of single degree of freedom systems; effect of damping; vibration isolation; resonance, critical speeds of shafts.

Design: Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as bolted, riveted and welded joints, shafts, spur gears, rolling and sliding contact bearings, brakes and clutches.

Fluid Mechanics and Thermal Sciences _____________

Fluid Mechanics: Fluid properties; fluid statics, manometry, buoyancy; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; viscous flow of incompressible fluids; boundary layer; elementary turbulent flow; flow through pipes, head losses in pipes, bends etc.

Heat-Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept, electrical analogy, unsteady heat conduction, fins; dimensionless parameters in free and forced convective heat transfer, various correlations for heat transfer in flow over flat plates and through pipes; thermal boundary layer; effect of turbulence; radiative heat transfer, black and grey surfaces, shape factors, network analysis; heat exchanger performance, LMTD and NTU methods.

Thermodynamics: Zeroth, First and Second laws of thermodynamics; thermodynamic system and processes; Carnot cycle. irreversibility and availability; behaviour of ideal and real gases, properties of pure substances, calculation of work and heat in ideal processes; analysis of thermodynamic cycles related to energy conversion.

Applications: Power Engineering: Steam Tables, Rankine, Brayton cycles with regeneration and reheat. I.C. Engines: air-standard Otto, Diesel cycles. Refrigeration and air-conditioning: Vapour refrigeration cycle, heat pumps, gas refrigeration, Reverse Brayton cycle; moist air: psychrometric chart, basic psychrometric processes. Turbomachinery: Pelton-wheel, Francis and Kaplan turbines - impulse and reaction principles, velocity diagrams.

Manufacturing and Industrial Engineering

Engineering Materials: Structure and properties of engineering materials, heat treatment, stress-strain diagrams for engineering materials.

Metal Casting: Design of patterns, moulds and cores; solidification and cooling; riser and gating design, design considerations.

Forming: Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes; principles of powder metallurgy.

Joining: Physics of welding, brazing and soldering; adhesive bonding; design considerations in welding.

Machining and Machine Tool Operations: Mechanics of machining, single and multi-point cutting tools, tool geometry and materials, tool life and wear; economics of machining; principles of non-traditional machining processes; principles of work holding, principles of design of jigs and fixtures.

Metrology and Inspection: Limits, fits and tolerances; linear and angular measurements; comparators; gauge design; interferometry; form and finish measurement; alignment and testing methods; tolerance analysis in manufacturing and assembly.

Computer Integrated Manufacturing: Basic concepts of CAD/CAM and their integration tools.

Production Planning and Control: Forecasting models, aggreGATE production planning, scheduling, materials requirement planning.

Inventory Control: Deterministic and probabilistic models; safety stock inventory control systems.

Operations Research: Linear programming, simplex and duplex method, transportation, assignment, network flow models, simple queuing models, PERT and CPM.

TOPIC WISE NUMBER OF QUESTIONS ANALYSIS

Mechanical Engineering (2005-2019)

Subject	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
General Aptitude No. of Questions	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10
Engg Mathematics No. of Questions	15	12	12	15	10	7	10	10	10	9	10	10	9	9	10
TECHNICAL SECTION															
Engineering Mechanics No. of Questions	6	2	2	3	2	0	4	4	1	6	5	4	2	2	3
Strength Of Materials No. of Questions	8	7	7	12	4	3	9	7	5	4	4	8	9	5	5
Theory Of Machines & Vibrations No. of Questions	8	12	7	4	6	9	4	4	5	3	5	4	4	5	4
Machine Design No. of Questions	3	4	9	7	3	2	0	0	5	4	3	3	1	2	4
Fluid Mechanics No. of Questions	6	10	9	4	4	9	3	3	4	6	8	7	7	5	4
Heat Transfer No. of Questions	6	4	6	5	5	1	3	4	6	5	1	4	2	3	4
Thermodynamics No. of Questions	11	7	7	11	7	6	10	4	6	6	4	4	9	7	7
Applications No. of Questions	3	2	2	2	1	1	1	4	0	1	3	–	–	–	–
Manufacturing & Industrial Engg No. of Questions	24	25	24	22	18	17	15	15	13	11	12	11	12	17	14

GATE MECHANICAL ENGINEERING SOLVED PAPER

2019 Set-1

Duration: 3 hrs **Maximum Marks: 100**

INSTRUCTIONS

1. There are a total of 65 questions carrying 100 marks.
2. The subject specific GATE paper section consists of 55 questions. The GA section consists of 10 questions.
3. Questions are of Multiple Choice Question (MCQ) or Numerical Answer type. A multiple choice question will have four choices for the answer with only one correct choice. For numerical answer type questions, the answer is a number and no choices will be given.
4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions will result in NEGATIVE marks. For all 1 mark questions, $\frac{1}{3}$ mark will be deducted for each wrong answer. For all 2 marks questions, $\frac{2}{3}$ mark will be deducted for each wrong answer.
5. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE.**

GENERAL APTITUDE TEST

QUESTIONS 1 TO 5 CARRY ONE MARK EACH

1. John Thomas, an .... writer, passed away in 2018.
(a) imminent (b) prominent
(c) eminent (d) dominant

2. .... I permitted him to leave, I wouldn't have had any problem with him being absent, ... I?
(a) Had, wouldn't (b) Have, would
(c) Had, would (d) Have, wouldn't

3. 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) 3.75 hours (b) 4 hours and 15 mins
(c) 8.5 hours (d) 7.5 hours

4. The sum and product or two integers are 26 and 165 respectively. The difference between these two integers is ....
(a) 2 (b) 3 (c) 4 (d) 6

5. 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) skirting
(c) tying (d) belting

QUESTIONS 6 TO 10 CARRY TWO MARKS EACH

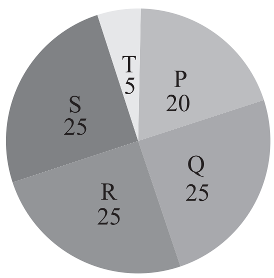
6. Under a certain legal system, prisoners are allowed to make one statement. If their statement turns out to be true then they are hanged. If the statement turns out to be false then they are shot. One prisoner made a statement and the judge had no option but to set him free. Which one of the following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

7. 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) 11 : 14
(c) 37 : 63 (d) 47 : 53

8. 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 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 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 Portuguese origin
(c) Mobuto's desire to Africanise names was prevented by the Portuguese
(d) As a dictator Mobuto ordered the Portuguese to alter the name of the river to Zaire

9. 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 employment at skill level S increased by 40% from 2010 to 2016. How many employees were there at skill level T in 2016?



Percentage share of skills in 2010

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

10. 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) M is the grandmother of Y
(c) W is the wife of R (d) W is the wife of P

TECHNICAL SECTION TEST

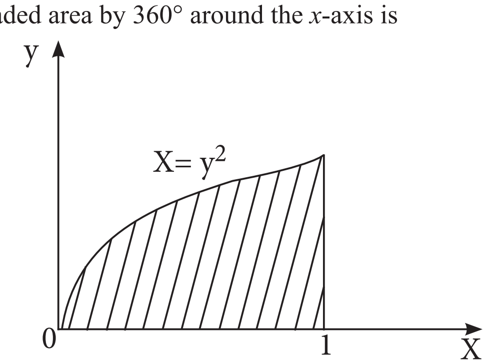
QUESTIONS 1 TO 25 CARRY ONE MARK EACH

1. 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) 0 (b) 1 (c) 2 (d) 3

2. 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

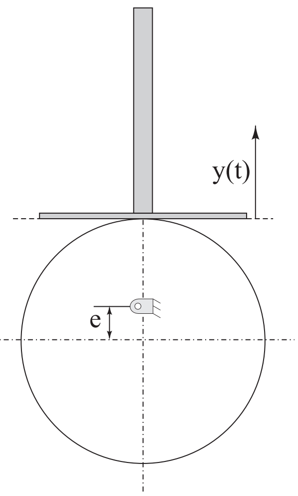


(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) π (d) 2π

3. For the equation $\frac{dy}{dx} + 7x^2 y = 0$, If $y(0) = 3/7$, then the value of $y(1)$ is
(a) $\frac{7}{3}e^{-7/3}$ (b) $\frac{7}{3}e^{-3/7}$
(c) $\frac{3}{7}e^{-7/3}$ (d) $\frac{3}{7}e^{-3/7}$

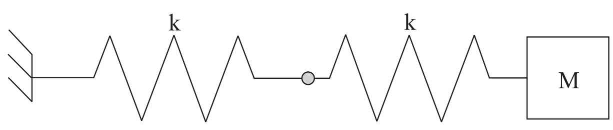
4. The lengths of a large stock of titanium rods follow a normal distribution with a mean (μ) of 440 mm and a standard deviation (σ) of 1 mm. What is the percentage of rods whose lengths lie between 438 mm and 441 mm?
(a) 81.85% (b) 68.4%
(c) 99.75% (d) 86.64%

5. 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.

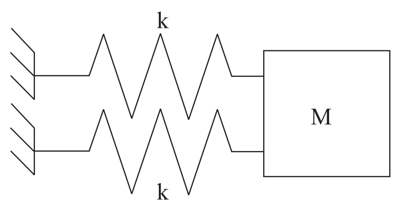


The vertical position of the follower face, $y(t)$ is given by
(a) $e \sin \omega t$ (b) $e(1 + \cos 2\omega t)$
(c) $e(1 - \cos \omega t)$ (d) $e \sin 2\omega t$

6. 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

7. 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) 0.73 kN
(c) 1.39 kN (d) 2.78 kN

8. 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) Isentropic (b) Polytropic
(c) Isothermal (d) Adiabatic

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

10. 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) Francis, Kaplan, Pelton
(d) Pelton, Kaplan, Francis

11. 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) $k_1 + k_2$ (b) $\sqrt{k_1 k_2}$
(c) $\frac{k_1 k_2}{k_1 + k_2}$ (d) $\frac{2k_1 k_2}{k_1 + k_2}$

12. 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) Coefficient of performance is the same as that of the original cycle.
(d) Refrigerating effect is lower than that of the original cycle.

13. 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) riser (d) pin hole

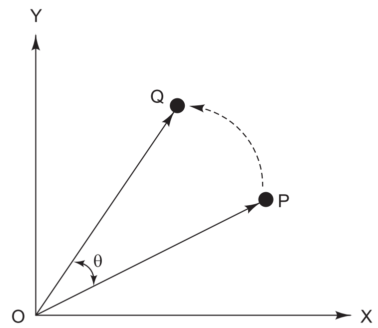
14. Which one of the following welding methods provides the highest heat flux (W/mm^2)?

(a) Oxy-acetylene gas welding
(b) Tungsten inert gas welding
(c) Plasma arc welding
(d) Laser beam welding

15. The length, width and thickness of a steel sample are 400 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 milling. The milling 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) 14 mm, 18.4 s (b) 21 mm, 28.9 s
(c) 21 mm, 39.4 s (d) 14 mm, 21.4 s

16. The position vector $\overrightarrow{OP}$ of point P (20, 10) is rotated anti-clockwise in X-Y plane by an angle θ = 30° 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) (22.32, 8.26)
(c) (12.32, 18.66) (d) (18.66, 12.32)

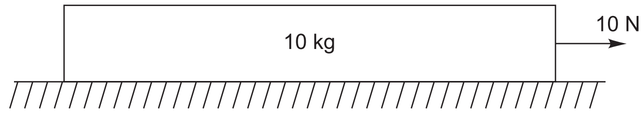
17. The table presents the demand of a product. By simple three-months moving average method, the demand-forecast of the product for the month of September is

Month	Demand
January	450
February	440
March	460
April	510
May	520
June	495
July	475
August	560

(a) 490 (b) 510 (c) 530 (d) 536.67

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

19. 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 ....



20. A cylindrical rod of diameter 10 mm and length 1.0 m is fixed at one end. The other end is twisted by an 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).

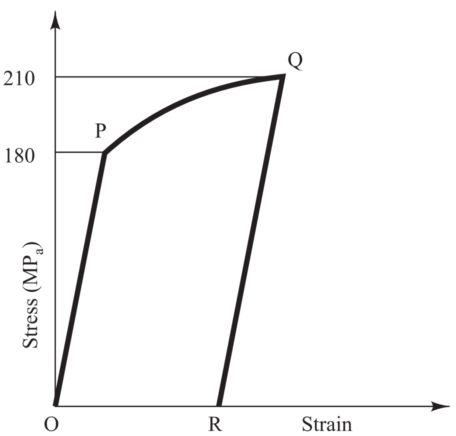
21. A solid cube of side 1 m is kept at a room temperature of 32°C. The coefficient of linear thermal expansion of the cube material is 1×10^{-5} / °C and the bulk modulus is 200 GPa. If the cube is constrained all around and heated uniformly to 42 °C, then the magnitude of volumetric (mean) stress (in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

22. 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)

23. 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.

24. 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 ....

25. 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.



QUESTIONS 26 TO 55 CARRY TWO MARKS EACH

26. The set of equations

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

has infinite solutions, if a =

(a) –3 (b) 3
(c) 4 (d) –4

27. A harmonic function is analytic if it satisfies the Laplace equation.

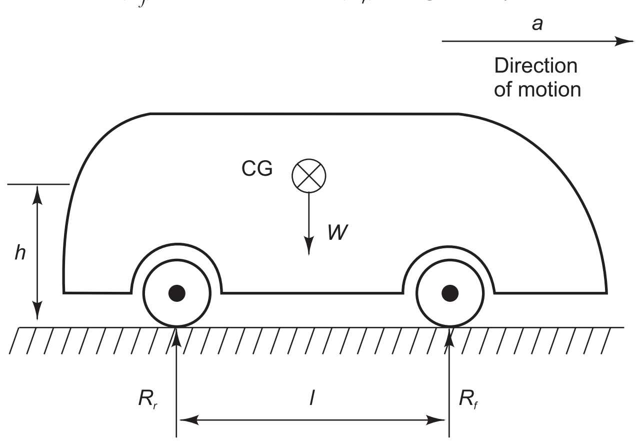
If $u(x, y) = 2x^2 - 2y^2 + 4xy$ is a harmonic function, then its conjugate harmonic function $v(x, y)$ is

(a) $4xy - 2x^2 + 2y^2$ + constant
(b) $4y^2 - 4xy$ + constant
(c) $2x^2 - 2y^2 + xy$ + constant
(d) $-4xy + 2y^2 - 2x^2$ + constant

28. 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) 0.33 (d) 0.50

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

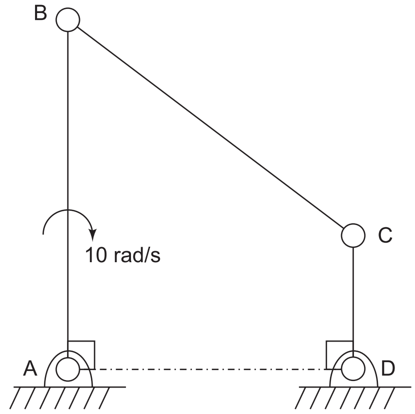
(b) $R_f = \frac{W}{2} + \frac{W}{g}\left(\frac{h}{l}\right)a$; $R_r = \frac{W}{2} - \frac{W}{g}\left(\frac{h}{l}\right)a$

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

30. 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



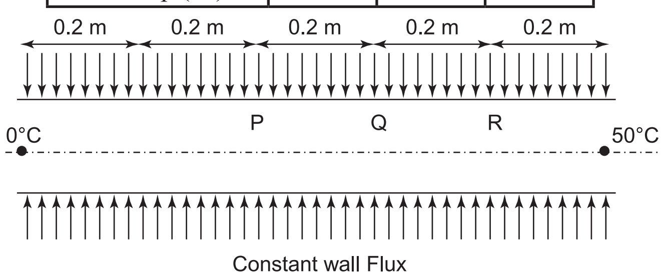
(a) 0 (b) 10
(c) 15 (d) 25

31. The rotor of a 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) 1629.6 N.m and the nose goes down
(c) 162.9 N.m and the nose goes up
(d) 162.9 N.m and the nose goes down

32. 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 ºC at the inlet and 50 ºC 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 (ºC)	50	80	90



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

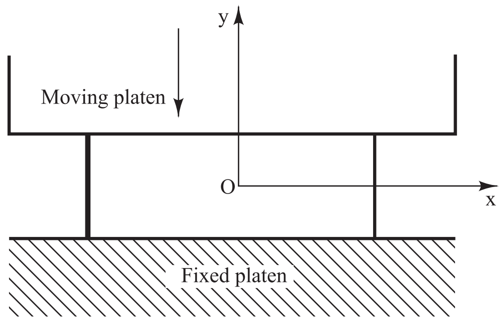
(a) P, Q and R (b) P and Q only
(c) Q and R only (d) R only

33. 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 ºC 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 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) 32 °C (b) 37 °C
(c) 53 °C (d) 76 °C

34. 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 σ_x = 40 MPa (compressive) and τ_{xy} = 0, the stress component σ_y is



(a) 340 MPa (compressive) (b) 340 MPa (tensile)
(c) 260 MPa (compressive) (d) 260 MPa (tensile)

35. In orthogonal turning of a cylindrical tube of wall thickness 5 mm, the axial and the tangential cutting forces were measured as 1259 N and 1601 N, respectively. The measured chip thickness after machining was found to be 0.3 mm. The rake angle 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 material is closest to

(a) 722 MPa (b) 920 MPa
(c) 200 MPa (d) 875 MPa

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

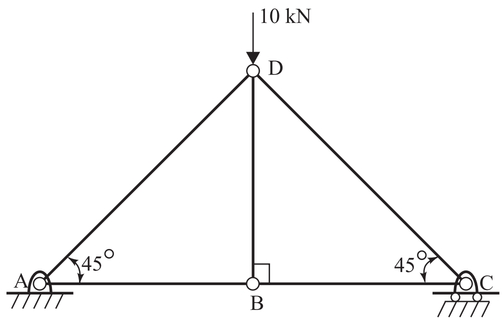
(a) 65.01 (b) 65.12
(c) 64.95 (d) 65.10

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

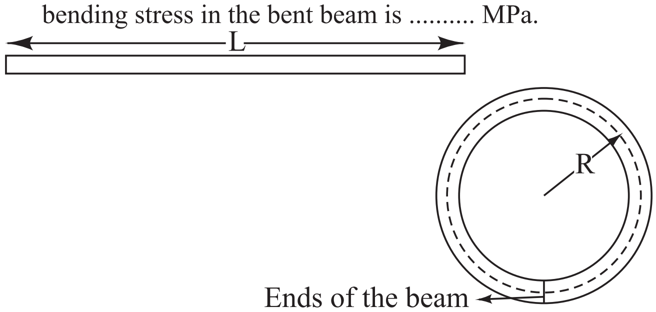
	Defect		Cause
P	Blow hole	1	Poor collapsibility
Q	Misrun	2	Mold erosion
R	Hot tearing	3	Poor permeability
S	Wash	4	Insufficient fluidity

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

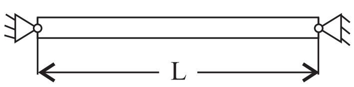
38. A truss is composed of members AB, BC, CD, AD and BD, as shown in the figure. A vertical load of 10 kN is applied at point D. The magnitude of force (in kN) in the member BC is ....



39. 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 Euler-Bernoulli beam theory is applicable to this bending problem, the maximum tensile bending stress in the bent beam is .... MPa.



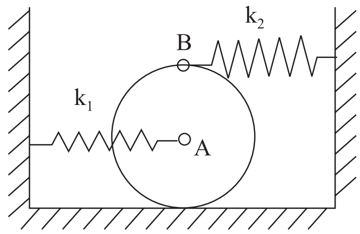
40. Consider a prismatic straight beam of length $L = \pi$ m, pinned at the two ends as shown in the figure. The beam has a square cross-section of side $p = 6$ mm. The Young's modulus $E = 200$ GPa, and the coefficient of thermal expansion $\alpha = 3 \times 10^{-6}$ K^{-1}. The minimum temperature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



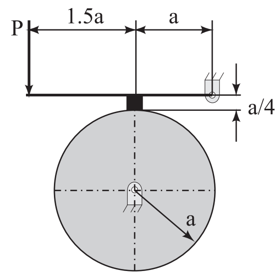
41. In a UTM experiment, a sample of length 100 mm, was loaded in tension until failure. The failure load was 40 kN. The displacement, measured using the cross-head motion, at failure, was 15 mm. The compliance of the UTM is constant and is given by 5×10^{-8} m/N. The strain at failure in the sample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

42. At a critical point in a component, the state of stress is given as $\sigma_{xx} = 100$ MPa, $\sigma_{yy} = 220$ MPa, $\sigma_{xy} = \sigma_{yx} = 80$ 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).

43. A uniform thin disk of mass 1 kg and radius 0.1 m is kept on a surface as shown in the figure. A 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. 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).



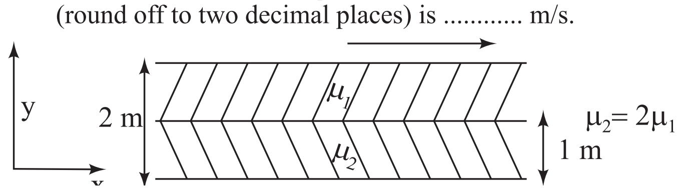
44. A single block brake with a short shoe and torque capacity of 250 N.m is shown. The cylindrical brake drum rotates anticlockwise at 100 rpm and the coefficient of friction is 0.25. The value of a, in mm (round off to one decimal place), such that the maximum actuating force P is 2000 N, is ....



45. 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

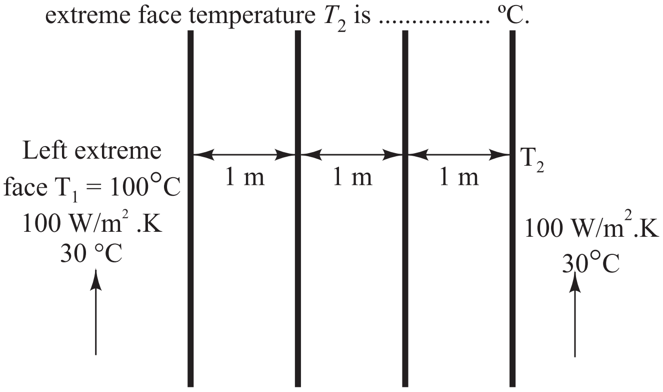
$$\frac{d^2u}{dy^2} = 0.$$

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



46. 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.

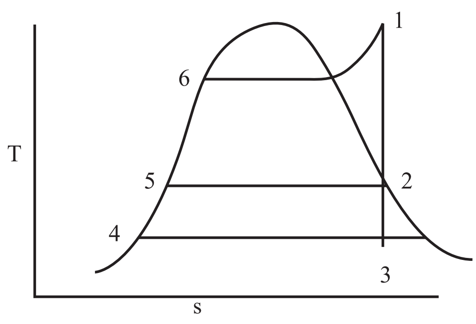
47. Three slabs are joined together as shown in the figure. There is no thermal contact resistance at the interfaces. The center slab experiences a non-uniform internal heat generation with an average value equal to 10000 Wm^{-3}, while the left and right slabs have no internal heat generation. All slabs 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 ºC 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 ºC, the right extreme face temperature T_2 is .... ºC.



48. If one mole of H_2 gas occupies a rigid container with a capacity of 1000 litres 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 behaviour, is .... Pa. (R=8.314J/mol.K)

49. 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 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 ....

50. 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 γ = 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)

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

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

52. 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 ....

53. 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 ....

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

55. 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______

HINTS & SOLUTIONS

GENERAL APTITUDE TEST

1. **(c)** Since the blank is preceded by 'an', option (b) and (d) are ruled out. The blank will take the word 'eminent', meaning (of a person) famous and respected within a particular sphere' while the word 'imminent', meaning 'about to happen' gets ruled out.

2. **(c)** The second blank will take the question tag 'would I?' because the auxiliary in the sentence is wouldn't; avoid talking about, so, options (A) and (D) get eliminated. Taking into consideration the past tense of the sentence, the past tense 'had' will make the sentence grammatically correct. Therefore, the correct answer is option (C).

3. **(d)** Angle related by hour hand in one hour

$= \frac{360°}{12} = 30°$

Angle rotated by hour hand in 1 minute

$= \frac{30°}{60} = \left(\frac{1}{2}\right)^{\circ}$

Time (in minute) required by hour hand to totate 225 degree

$= 225 \times 2 = 150$ minutes $= 7.5$ hours.

4. **(c)** Let the two integers are x and y, such that $x > y$.

then, *ATQ*,

$x + y = 26$

$x \cdot y = 165$

Now, $(x-4)^2 = (x+y)^2 - 4xy$

$= (26)^2 - 4 \times 165$

$= 676 - 660 = 16$

$\therefore x - y = 4.$

5. **(b)** The word 'skirting which means' fills the blank correctly. Rest of the options are irrelevant in the context of the sentence.

6. **(c)** If prisoner made a statement 'I will be shot'. Then judge has no option but to set him free.

There are two cases:

Case I: When prisoner statement is true 'I will be shot'. Then judge will hang him but according to statement prisoner should have been shot.

So, this is not valid conclusion.

Case II: When prisoner statement is false. 'I will be shot'. Then judge will shot him. But this action made his statement true. Thus, this is also not a valid conclusion.

Hence, in all cases, judge has to set him free.

7. **(d)** Let the person have divided the amount in two schemes in ₹ x and $(100000 - x)$.

then, ATQ,

$1.1x + 1.12(100000 - x) - 1.12x - 1.1(100000 - x) = 120$

$-0.02x + 2000 - 0.02x = 120$

$0.04x = 1880$

$x = \frac{1880 \times 100}{4} = 47000$

Amount spent in another scheme

$= 100000 - 47000 = 43000$

Required ratio $= 47000 : 43000 = 47 : 43$

8. **(a)**

9. **(c)** Number of employees in 2016

$= 600 \times \frac{115}{100} = 690$

Number of employees in 2010

at skill level $S = 600 \times \frac{25}{100} = 150$

Number of Employ in 2016

at skill level $S = 150 \times \frac{140}{100} = 210$

$\therefore$ Number of employees at skill level S in 2016

$= 690 - 420 - 210 = 60$

10. **(d)** According to the question, x and y are the child of P and Q respectively.

So, y is Q's child and legitimate child of W.

Hence, W is the wife of P is necessarily false.

TECHNICAL ABILITY TEST

1. **(b)** 2. **(b)** 3. **(c)**

4. **(a)** Given data : mean $(\mu) = 440$ mm

Standard deviation $(\sigma) = 1$ mm

Variation of lengths of rod $(dx) = 438$ mm to 441 mm using the relation,

$Z = \frac{dx - \mu}{\sigma}$

Where, Z = standardized normal variable

At $dx = 438$ mm, then

$Z_1 = \frac{438 - 440}{1}$

$Z_1 = -2$

Percentage of rods (P_1) at $Z_1 = -2$

$P_1 = 2.28\%$ **(Approx.)**

At $dx = 441$ mm, then,

$Z_2 = \frac{441 - 440}{1}$

$Z_2 = 1$

Percentage of rods (P_2) at $Z_2 = 1$,

$P_2 = 84.13\%$ **(Approx.)**

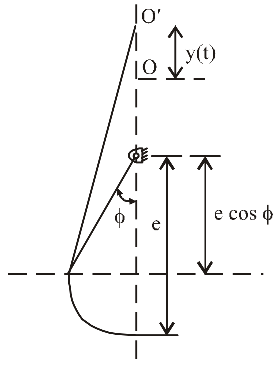
Now, $P = P_1 + P_2$

$= -2.28 + 84.13$

$= 81.85\%$

where, P = Percentage of rods whose length lie between 438 mm and 441 mm.

5. **(c)** Given data : For a flat-faced follower,
Angular velocity (constant) = ω
Vertical position of followed, at $t = 0$
$y(0) = 0$
Refer to following figure,



Here, $OO' = y = e - e\cos\phi$
$= e(1 - \cos\phi)$
$= e(1 - \cos\omega t)$

6. **(b)** Given data :
For a spring-mass systems,
w_I = natural frequency for spring-mass system I
w_{II} = natural frequency for spring-mass system II
For system-I,

Equivalent stiffness, $K_{eq} = \frac{K \cdot K}{K + K} = \frac{K^2}{2K} = \frac{K}{2}$

$\therefore \quad w_I = \sqrt{\frac{K_{eq.}}{M}} = \sqrt{\frac{K}{2M}}$ ...(i)

For system-II,
Equivalent stiffness, $K_{eq.} = K + K = 2K$

$\therefore \quad w_{II} = \sqrt{\frac{K_{eq.}}{M}} = \sqrt{\frac{2K}{M}}$ ...(ii)

Dividing Eqn. (i) by Eqn. (ii), we get

$$\frac{w_I}{w_{II}} = \frac{\sqrt{\frac{K}{2M}}}{\sqrt{\frac{2K}{M}}} = \sqrt{\frac{K}{2M}} \times \sqrt{\frac{M}{2K}}$$

$$\frac{w_I}{w_{II}} = \sqrt{\frac{K \times M}{2M \times 2K}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

7. **(b)** Given data: For spur gear,
Pressure angle; $\phi = 20°$
Power transmitted, P = 20 kw
angular speed, ω = 200 rad/s
Pitch circle diameter $(d_p) = 100$ mm

$$= \frac{100}{1000} = 0.1 \text{ M}$$

Using the following relation,
P = T.ω
where, T = torque applied
ω = Angular speed

$$\therefore \quad T = \frac{P}{\omega} = \frac{20 \times 10^3}{200} = 100 \text{ N}m$$

Using the relation,
$T = F_t \times r_P$

$$100 = F_t \times \frac{d_p}{2}$$

$$100 = F_t \times \frac{0.1}{2}$$

$$100 = F_t \times 0.05$$

$$F_t = \frac{100}{0.05} = 2000\text{N}$$

Now, we know that,

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

where, F_g = Force applied on the gear in radial direction

$\therefore \quad F_g = F_t \tan\phi$
$= 2000 \times \tan 20°$
$= 2000 \times 0.3639$
$= 727.8$ N

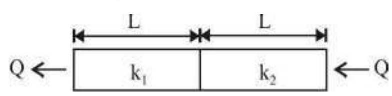
$F_g \approx 0.73$ kN

8. **(c)** In a isothermal process, the temperature remains constant i.e. change of temperature (dT) is equal to zero. During a non-flow thermodynamic process (1–2). According to first law of thermodynamics
$\Delta U = 0 = Q_{1-2} - w_{1-2}$
$\therefore Q_{1-2} = w_{1-2}$
Here, ΔU = change of internal energy
Q_{1-2} = Heat interaction
w_{1-2} = work interaction

9. **(a)** Given data:
For a circular pipe of constant cross-section,
Nu_q = Nusselt number of constant wall heat flux
Nu_T = Nusselt number at constant wall temperature
Here, $Nu_q = 4.35$, and $Nu_T = 3.65$
$\therefore Nu_q > Nu_T$

10. **(a)** Let, Q_K = flow rate of Kaplan turbine
Q_F = flow rate of Francis turbine
Q_P = flow rate of Pelton turbine
$\therefore Q_K > Q_F > Q_P$

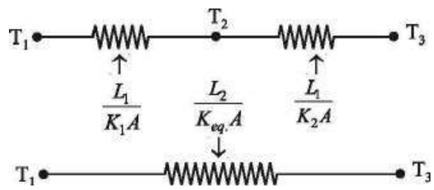
11. **(d)** Given data:
For Slinder rod '1'
$L_1 = L$ = Length, d = diameter, (L >> d)
K_1 = thermal conductivity
For Slinder rod '2'
L_2 = Length = 2L, d = diameter, K_2 = thermal conductivity
Refer to figure,



Let, T_1, T_3 = temperature of rods 1 and 2 respectively
T_2 = temperature at junction
Q = Heat flow through composite

A = cross-sectional area of rod

Considering the following circuit



Now, heat flow rate, Q

$$= \frac{T_1 - T_3}{\frac{L_1}{K_1 A} + \frac{L_1}{K_2 A}} = \frac{T_1 - T_3}{\frac{L}{K_1 A} + \frac{L}{K_2 A}} = \frac{T_1 - T_3}{\frac{2L}{K_{eq.} A}}$$

Here, $\frac{2L}{K_{eq.} A} = \frac{L}{K_1 A} + \frac{L}{K_2 A}$

$$\frac{L}{A}\left(\frac{2}{K_{eq.}}\right) = \frac{L}{A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)$$

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

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

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

12. **(a)** For an ideal vapour compression refrigeration cycle Let, $(CoP)_1$ = Coefficient of performance of original cycle $(CoP)_2$ = Coefficient of performance of cycle after replacing throttling process by isentropic expansion process $(CoP)_2 > (CoP)_1$

13. **(b)** 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 sprue. A sprue is a hole in the mold where molten metal enters. It holds the wax pattern for the purpose of avoiding distortion.

14. **(d)** Laser Beam Welding (LBW) is a fusion welding process in which two metal parts (Plates or pieces) are joined together by utilizing laser. The laser beams have high amount of energy (highest heat flux) and when it striker the metal parts devolops heat that melts the material from the two metal parts and fills the cavity.

15. **(d)** Given data :

For milling cutter,

Diameter (D)	=	100 mm
thickness (t)	=	2 mm
width (b)	=	50 mm
Number of teeth (Z)	=	20
Rotational speed (N)	=	1200 rpm
feed rate (f)	=	0.05 mm

Approach distance $= \sqrt{t(D-t)} = \sqrt{2(100-2)}$

$= \sqrt{2 \times 98} = \sqrt{196} = 14\text{ mm}$

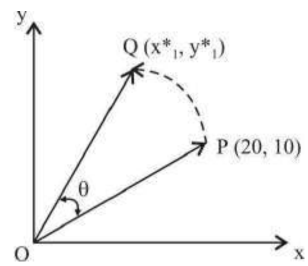
Machining time $= \left[\frac{l + 14 + 14}{f\,z\,N}\right]$

where, l = length of steel sample = 400 mm (given)

$\therefore$ Maching time $= \frac{400 + 14 + 14}{0.05 \times 20 \times 1200}$

$= \frac{428}{1200} = 0.356\text{ min.} = 21.4\text{ sec.}$

16. **(c)** Refer to the figure given below:



Given data θ = 30º, co-ordinates of point P = (20, 10)

Let (x^*, y^*) be the co-ordinates of θ after transformation by θ. Then,

$$\begin{bmatrix} x^* \\ y^* \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} 20 \\ 10 \end{bmatrix}$$

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

$$\begin{bmatrix} x^* \\ y^* \end{bmatrix} = \begin{bmatrix} 20\cos 30^\circ & -10\sin 30^\circ \\ 20\sin 30^\circ & +\cos 30^\circ \end{bmatrix} \begin{bmatrix} 20 \\ 10 \end{bmatrix}$$

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

$$\begin{bmatrix} x^* \\ y^* \end{bmatrix} = \begin{bmatrix} 17.32 & -\ 5 \\ 10 & +8.66 \end{bmatrix}$$

$$\begin{bmatrix} x^* \\ y^* \end{bmatrix} = \begin{bmatrix} 12.32 \\ 18.66 \end{bmatrix}$$

$(x^*, y^*) = (12.32, 18.66)$

17. **(b)** Given data :

Demands: For month:

D_1 (August)	= 560
D_2 (July)	= 475
D_3 (June)	= 495

By using simple three months moving average method, demand forecast for September

$$= \frac{D_1 + D_2 + D_3}{3} = \frac{560 + 475 + 495}{3}$$

$$= \frac{1530}{3} = 510$$

18. **(63)**

19. **(10)** **Given:** Mass of block, m = 10 kg

Acceleration due to gravity, $g = 9.81\text{ m/s}^2$

Coefficient of friction, μ = 0.2

horizontal force, F = 10 N

Let, F_f = Force of friction
Maximum frictional force, $F_{f\,(max.)} = \mu R$
$= 0.2 \times mg = 0.2 \times 10 \times 9.81 = 19.62\ N$
Here, $F < F_{f(max.)}$
hence, $F_f = F = 10\ N$

20. (0.87)
Given data: diameter of cylindrical rod, D = 10 mm
Length of cylindrical rod, L = 1 m
Angle of twist, $\theta = 10°$
Maximum shear strain, $\phi_{(max.)} = P \times 10^{-3}$
Using the torsion Equation, we get

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

from the above relation, $\frac{\tau}{R} = \frac{G\theta}{L}$

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

or, $\phi_{max.} = \frac{R\theta}{L}$

or, $P \times 10^{-3} = \frac{\frac{10}{2} \times 10 \times \frac{\pi}{180}}{1 \times 10^3} \quad \left[\because R = \frac{P}{2} = \frac{10}{2}\right]$

P $= 0.872$
P ≈ 0.87

21. (60) MPa Given: Side of solid cube, $a = 1$ m
Room temperature, $t_1 = 32°C$
Coefficient of linear expansion, $\alpha = 1 \times 10^{-5} / °C$
Both Modular, K = 200 GPa
$t_2 = 42°C$
As we know that the cube is constrained all around hence the state of hydrostatic stress is being developed. then,

Volumetric strain $(e_v) = \frac{\sigma_v}{K} = 3\alpha\Delta t$

Where, σ_v = volumetric stress
$\Delta t = t_2 - t_1 = 42 - 32 = 10°C$
$\therefore \sigma_v = 3 \cdot \alpha \cdot \Delta t \cdot k$
$= 3 \times 1 \times 10^{-5} \times 10 \times 200 \times 10^9$
$= 60 \times 10^6\ N/m^2$ or 60×10^6 pa = 60 MPa

22. (–0.2) Given data:
During a high cycle fatigue test,
Mean stress, $\sigma_{mean} = +140$ MPa
Minimum stress, $\sigma_{min.} = -70$ MPa
Let, $\sigma_{max.}$ = maximum stress
using the relation

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

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

$2 \times 140 = \sigma_{max.} - 70$
$\sigma_{max.} = 280 + 70 = 350$ MPa

Now, ratio : $\frac{\sigma_{min.}}{\sigma_{max.}} = \frac{-70}{350} = -0.2$

23. (3) m/s², Given data :

Velocity, $\bar{v} = \left(\frac{4}{t} + x + y\right)\hat{j}$ m/s

where, $\hat{j}$ = unit vector in y-direction
$t > 0$ (seconds)
Here, $u = 0$ and $w = 0$

then, $a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = 0$

and $a_z = \frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = 0$

$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}$

$= \frac{\partial v}{\partial t} + v\frac{\partial u}{\partial y} \quad \{\because u = 0, w = 0\}$

$= \frac{\partial}{\partial t}\left(\frac{4}{t} + x + y\right) + \left(\frac{4}{t} + x + y\right)\frac{\partial}{\partial y}\left(\frac{4}{t} + x + y\right)$

$= \left(-\frac{4}{t^2} + 0 + 0\right) + \left(\frac{4}{t} + x + y\right)(1)$

$a_y = -\frac{4}{t^2} + -\frac{4}{t} + x + y$

Now, a_y at (1, 1) i.e., $x = 1, y = 1$ and $t = 2$s, hence

$a_y = -\frac{4}{(2)^2} + \frac{4}{2} + 1 + 1$

$= -1 + 2 + 1 + 1$
$a_y = 3\ m/s^2$

Total acceleration, $a_T = \sqrt{a_x^2 + a_y^2 + a_z^2}$

$= \sqrt{(0)^2 + (3)^2 + (0)^2} = \sqrt{9} = 3\ m/s^2$

24. (0.66) KJ/kg–k
Given data :
Mass of air, $m = 1$ kg
Initial condition
$T_1 = 300$ K
$P_1 = 10$ bar
Final conditions:
$P_2 = 1$ bar
Ideal gas constant, R = 0.287 kJ/kg-k
Let, $ds = S_2 - S_1$ = Change in entropy

$dQ = m RT \ln\frac{P_1}{P_2}$ = change in internal energy

then, $ds = \frac{dQ}{T} = \frac{mRT \ln\left(\frac{P_1}{P_2}\right)}{T}$

$= mR \ln\left(\frac{P_1}{P_2}\right)$

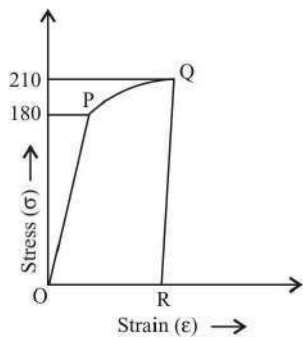
$= 1 \times 0.287 \times \ln\left(\frac{10}{1}\right)$

$= 0.287 \times \ln(10) = 0.287 \times 2.3026$

$ds = 0.66$ kJ/kg-k

25. (210) MP*a*

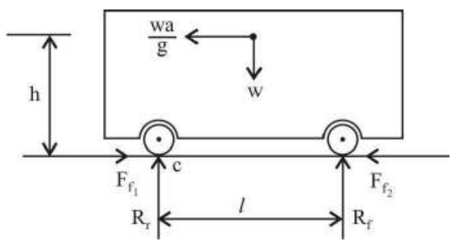
Refer to figure given below:



After reloading of the material in tension from point R, the yield strength again increases upto 210 MPa because of strain hardening.

26. (c) 27. (a) 28. (b)

29. (c) Refer to figure showing free body diagram of car given below:



Given data: w = weight of car

l = distance between front and rear wheels

a = acceleration of a car

g = acceleration due to gravity

R_f = Reaction on front wheel

R_r = Reaction on rear wheel

h = height from the ground

Let, F_{f1} = frictional force acting on front wheel

F_{f2} = frictional force acting on rear wheel

$\Sigma_v = 0, R_r + R_f - w = 0$

$$R_r + R_f = w \quad \text{...(i)}$$

$\Sigma M_c = 0,$

$$w \times \frac{l}{2} - R_f \times l - \left(w \times \frac{a}{g}\right) \times h = 0$$

$$R_f \times l = \frac{wl}{2} - \left(\frac{wa}{g}\right) \times h$$

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

Substituting the value of R_f in eqn. (i), we have

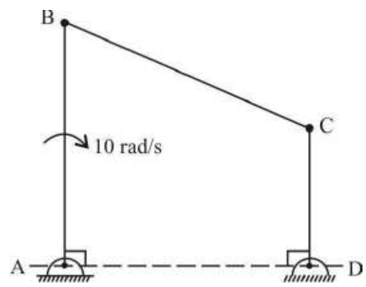
$$R_r + \frac{w}{2} - \frac{w}{g}\left(\frac{h}{l}\right)a = w$$

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

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

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

30. (d) Refers to figure given below:



Given data: AB = 5 cm, AD = 4 cm DC = 2 cm

Angular velocity of bar AB, w_{AB} = 10 rad/s

From the figure, we can write the following relation,

$w_{AB} \times AB = w_{DC} \times DC$

where, w_{DC} = Angular velocity of bar DC

$10 \times 5 = w_{DC} \times 2$

$$w_{DC} = \frac{50}{2} = 25 \text{ rad/s}$$

31. (b) Given data: mass of rotor, m = 180 kg

Polar moment of inertia, I = 10 kg–m^2

Rotational speed of rotor, ω = 1100 rad/s

Speed of aircraft, v = 800 km/h

turning radius, R = 1.5 km

$$\text{Now, } \omega_p = \frac{v}{R} = \frac{\frac{800 \times 1000}{3600}}{1.5 \times 1000} = 0.148 \text{ rad/s}$$

Now, Gyroscopic moment at point (c)

$= I w \omega_p = 10 \times 1100 \times 0.148$

$C = 1628 \approx 1629.6$ Nm

Hence, nose goes down and fail goes up.

32. (c) Given data :

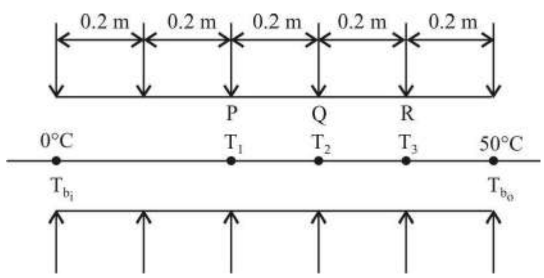
Bulk temperature of fluid at inlet, T_{b_i} = 0ºC

Bulk temperature of fluid at outlet, T_{b_o} = 50ºC

Let, T_1, T_2, and T_3 are the wall temperature at location P, Q and R.

$\therefore T_1' = 50ºC, T_2' = 80ºC, T_3' = 90ºC$

Length of pipe having constant diameter, l = 1m



Balance of energy between T_{b_i} and T_{b_o},

$\dot{q}\times\pi dl = \dot{m}C_p(T_{b_o}-T_{b_i})$

$\dot{q}\times\pi\times d\times l = \dot{m}C_p(50-0)$

$$\dot{q} = \frac{50\dot{m}C_p}{\pi d}$$

Balance of energy between T_{b_i} and T_1

$\dot{m}C_p(T_2-T_{b_i}) = \dot{q}\times\pi\times d\times(0.2+0.2)$

or, $\dot{m}C_p(T_2-0) = 0.4\times\dot{q}\times\pi\times d$

or, $\dot{m}C_p\times T_2 = \frac{0.4\times 50\dot{m}C_p}{\pi d}\times\pi d$

$T_2 = 20ºC$

Energy balance between T_{b_i} and T_3

$\dot{m}C_p(T_3-T_{b_i}) = \dot{q}\times\pi\times d\times(0.2+0.2+0.2)$

or, $\dot{m}C_p(T_3-0) = \dot{q}\times\pi\times d\times 0.6$

$\dot{m}C_p\times T_3 = \frac{50\dot{m}C_p}{\pi d}\times\pi d\times 0.6$

$T_3 = 50\times 0.6 = 30ºC$

Energy balance between T_{b_i} and T_u

$mC_p(T_u-T_{b_i}) = q\times\pi\times d\times(0.2+0.2+0.2+0.2)$

$mC_p(T_u-0) = q\times\pi\times d\times 0.8$

$mC_p\times T_u = \frac{50\dot{m}C_p}{\pi d}\times\pi\times d\times 0.8$

$T_u = 50\times 0.8 = 40ºC$

Using the following relation,

Nusselt number, $(Nu) = \frac{hd}{K}$

$4.36 = \frac{hd}{K}$

$\Rightarrow h = 4.36\times\frac{K}{d}$ [Here, K and d are constant]

Now, uniform heat flux, $q'' = h\cdot dT$

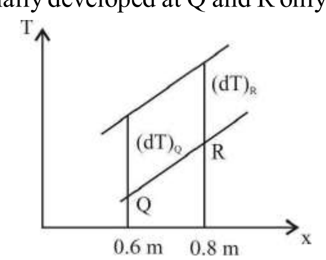
Where, h = constants dT = constant

Now, $(dT)_p = T_1' - T_2 = 50-20 = 30°C$

$(dT)_Q = T_2' - T_3 = 80-30 = 50°C$

$(dT)_R = T_3' - T_4 = 90-40 = 50°C$

from the above data, $(dT)_Q = (dT)_R$ hence the flow is thermally developed at Q and R only.



33. (a) Given data : At entry:

Pressure, $P_1 = 100$ kPa

temperature, $T_1 = 27+273 = 300$ K

Volume flow rate, $V_1 = 15\ m^3/s$

heat lost to surrounging, $\frac{dQ}{dT} = 51$ kw

Considering the SFEE (Steady Flow Energy Equation) are given:

$$\dot{m}\left[H_1+\frac{V_1^2}{2000}\right]+\frac{dQ}{dt} = \dot{m}\left[H_2+\frac{V_2^2}{2000}\right]+\frac{dw}{dt}$$

Where, $\dot{m} = \frac{P_1V_1}{RT_1} = \frac{100\times 15}{0.5\times 300} = 10$

H_1, H_2 = initial and final enthalpies

V_1, V_2 = flow velocities at inlet and outlet

$\therefore\ H_1 = C_P\cdot T_1 = 1\times 300 = 300$

$H_2 = C_P\cdot T_2 = 1\times T_2 = T_2$

$V_1 = 0$

$V_2 = 0$

$\frac{dw}{dt} = 0$

Now, $10[300+0]+(101-51) = 10\times(T_2)$

$3000+50 = 10T_2$

$T_2 = 300+5 = 305°K$

or, $t_2 = T_2 - 273$

$= 305-273$

$t_2 = 32ºC$

34. (a) Given data : Strain in z-direction, $\Sigma_z = 0$

yield strength of block, $\sigma_{yt} = 300$ MPa

At a point, $\sigma_x = 40$ MPa (compressive)

$\tau_{xy} = 0$

According to Trisca's criterion,

$$\sigma_1 = \frac{(\sigma_x+\sigma_y)}{2}$$

where, σ_1 = Principal stress

Here, σ_x = maximum stress

σ_y = minimum stress

then, $\sigma_x - \sigma_y = \sigma_{yt}$

$-40-\sigma_y = 300$

$-40-300 = \sigma_y$

$\sigma_y = -340$ MPa

$= 340$ MPa (Compressive)

35. (a) Given data : wall thickness of cylindrical tube, $t' = 5$ mm

Axial cutting force (or feed force) $= F_a = 1259$N

tangential force, $F_t = 1601$ N

chip thickness, $t_2 = 0.3$ mm

rake angle $(\alpha) = 10º$

axial feed, $(f) = 100$ mm / min

Rotational speed (N) = 1000 rpm

uncut chip thickness, $t_1 = 0.1$ mm

chip thickness ratio, $r = \frac{t_1}{t_2} = \frac{0.1}{0.3} = \frac{1}{3}$

Assuming, $y_s = 0$, then

$F_a = F_{th.}$

where, F_{th} = thrust force

$F_{th} = F_a = 1259$ N

Now, using the relation,

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

$$\tan\phi = \left[\frac{\frac{1}{3}\times\cos 10^{\circ}}{1-\frac{1}{3}\sin 10^{\circ}}\right]$$

$$= \frac{0.33\times 0.9848}{1-0.33\times 0.1736} = \frac{0.3249}{1-0.05728} = \frac{0.3249}{0.9427}$$

$\tan\phi = 0.3446$

$\phi = \tan^{-1}(0.3446)$

$\phi = 19.01°$

Refer to figure given below:

Now, considering $\Delta OAA'$, we get

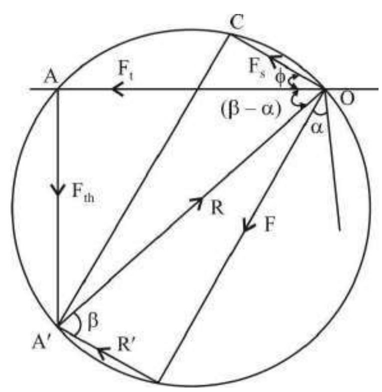
$$\tan(\beta-\alpha) = \frac{F_{th.}}{F_t} = \frac{1259}{1601}$$

$\tan(\beta-\alpha) = 0.786$

$(\beta-\alpha) = \tan^{-1}(0.786)$

$\beta - \alpha = 38.16°$

Again, considering $\Delta OCA'$, we get



Shear force, $F_s = R\cos(\beta + \phi - \alpha)$

$$\text{Where, } R = \sqrt{F_t^2 + F_a^2} = \sqrt{(1601)^2 + (1259)^2}$$

$$= \sqrt{2563201 + 1585081} = 2036.73 \text{ N}$$

$\therefore$ $F_s = 2036.73\cos(19.01 + 38.16)$

$F_s = 2036.73\cos(37.17)$

$= 1104.20$N

Now, width to be cut = tube thickness = 5 mm

$$\text{Now, } \tau_s = \frac{F_s}{A_s}$$

where, τ_s = shear strength

$$A_s = \frac{w\times t_1}{\sin\phi} = \frac{5\times 0.1}{\sin 19.01} = \frac{0.5}{0.326}$$

$= 1.533\text{N/mm}^2$

$$\tau_s = \frac{1104.20}{1.533} = 720.28\text{N/mm}^2$$

or 720.28 MPa

$\tau_s \approx 722$ MPa

36. **(b)** Given data :

diameter of circular shaft, $= 65.00^{+0.01}_{-0.05}$ mm

thickness of coating = 50 μm

variation in thickness = ±5μm

coating thickness for circular shaft,

$t_1 = 50 + 5\mu m = 55\ \mu m \approx 0.055$ mm

$t_2 = 50 - 5\mu m = 45\ \mu m \approx 0.045$ mm

minimum hole diameter to just provide clearance fit,

Upper control limit before coating,

UCL = 65.00 + 0.01 = 65.01 mm

Now, upper control limit after coating, UCL

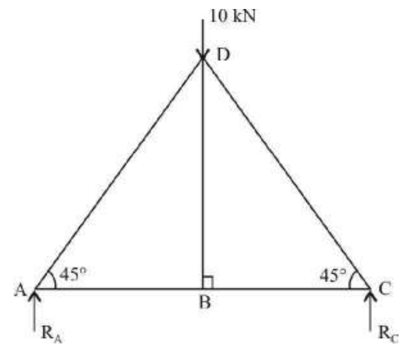
$= 65.01 + 2\times 0.055 = 65.01 + 0.11 = 65.12$ mm

37. **(d)**

Sand molding casting defects		**Respective causes**
Blow hole	⇒	Poor permeability
Misrun	⇒	Insufficient fludity
Hot fearing	⇒	Poor collapsibility
Wash	⇒	Mold erosion

38. **(5)** **kN**

considering the following truss or shown figure:



From the geometry of figure, ΔABD and ΔDBC are identical

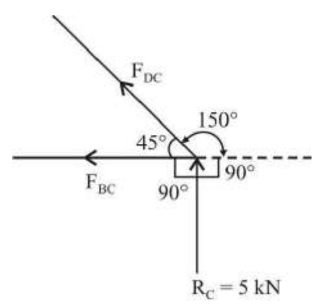
$\therefore R_A = R_C$

$R_A + R_C = 10$

$2R_A$ or $2R_C = 10$

$R_A = R_C = 5$ KN

Considering joint 'C',



Let us consider, F_{DC} = tensile force

F_{BC} = tensile force

Applying Lami's theorem, we get,

$$\frac{R_C}{\sin 45^o} = \frac{F_{DC}}{\sin(150+90)} = \frac{F_{BC}}{\sin(45+90+90)}$$

or, $$\frac{F_{BC}}{\sin(225^o)} = \frac{F_{DC}}{\sin(240^o)} = \frac{5}{\sin 45^o}$$

$$F_{BC} = \frac{5}{\sin 45^o} \times \sin 225^o$$

$$= \frac{5}{0.707} \times -0.707$$

$F_{BC} = -5KN$

39. (100) MPa

Given data:

Length of elastic beam, $L = 10\,\pi\, m$

side of square cross-section, a = 5 mm

Young's modulur, E = 200 GPa

mean radius of circle, = R

Using the following relation,

$$\sigma_b = \frac{E}{R} \times y_{max.}$$

where, σ_b = maximum bending stress (tensile)

$$y_{max.} = \frac{a}{2} = \frac{5}{2} = 2.5\ mm$$

considering also, $L = 2\pi R$

$10\pi = 2\pi R$

$$R = \frac{10\pi}{2\pi} = 5m = 5 \times 10^3 \text{ mm}$$

$$\therefore \sigma_b = \frac{200 \times 10^9 \times 10^{-6}}{5 \times 10^3} \times 2.5$$

$$= \frac{200}{5} \times 2.5 = 100 \text{ N/mm}^2 = 100 \times 10^6 \text{ N/m}^2$$

$\therefore \sigma_b = 100$ MPa

40. (1ºK)

Given data : Length of beam, $L = \pi\, m$

Side of beam, x = 6 mm

Young's Modulus, E = 200 GPa

Coefficient of thermal empansion, $\alpha = 3 \times 10^{-6}$ /ºK

Considering the following relation,

$$\text{Euler's buckling load, } P_e = \frac{\pi^2 ET}{L_e^2}$$

$$\text{where, I = Moment of inertia} = \frac{x^4}{12}$$

L_e = effective length

= L (for both ends hinged)

$$\therefore \quad P_e = \frac{\pi^2 E \times \frac{x^4}{12}}{L^2} = \frac{\pi^2 E x^4}{12 L^2} \quad ..(i)$$

Thermal stress, $\sigma_{th.} = E\,\alpha\, t$

Thermal Load, $P_e = \sigma_t \times A$

$P_{th.} = (E\,\alpha\, t)A$ ...(ii)

Equating (i) and (ii), we have,

$P_{th.} = P_e$

$$(E\alpha t)A = \frac{\pi^2 E x^4}{12 L^2}$$

$$\alpha\, t A = \frac{\pi^2 x^4}{12 L^2}$$

$$t = \frac{\pi^2 x^4}{12 L^2 \times \alpha \cdot A} = \frac{\pi^2 x^4}{12 L^2 \times \alpha \times x^2}$$

$$= \frac{\pi^2 x^2}{12 L^2 \times \alpha}$$

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

t = 1ºk

41. (13.1)

Given data: In a universal Testing Machine (UTM),

Length of sample (or specimen) L = 100 mm

Load at failure, P = 40 kN

displacement (or deformation) at failure,

$\delta L' = 15$ mm

Compliance of UTM(K′) = 5×10^{-8} m/N

Using the following relation,

$$K' = \frac{L}{AE} \quad ..(i)$$

$$\text{and, } \delta L = \frac{PL}{AE} \quad ...(ii)$$

where, L = original length of specimen

E = Young's Modulur

A = Area of cross-section

Now, using eqn. (ii),

$$\delta L = \frac{PL}{AE} \text{ or } I = AE \times \frac{\delta L}{L}$$

$$\text{or } P = \frac{\delta L}{\frac{L}{AE}} = \frac{\delta L}{K'}$$

$$40 \times 10^3 = \frac{\delta L}{5 \times 10^{-8}}$$

$\delta L = 40 \times 10^3 \times 5 \times 10^{-8} = 2 \times 10^{-3}$ m

$$\text{Strain, } e = \frac{\delta L}{L} = \frac{2 \times 10^{-3}}{100 \times 10^{-3}} = 0.02 \approx 2\%$$

$$\text{Total strain, } e_T = \frac{\delta L'}{L} = \frac{15}{100} = 0.15 \approx 15\%$$

$\therefore$ Strain at failure in sample = 15 – 2 = 13%

42. (1.8)

Given data : At a critical point in a component, state of stress

σ_{xx} = 100 MPa, σ_{yy} = 220 MPa, $\sigma_{xy} = \sigma_{yx}$ = 80 MPa

Yield strength of material, $\sigma_{yt.}$ = 468 MPa

Let, σ_1 and σ_2 = Maximum and minimum principal stresses then, according to maximum shear stress theory;

$$\tau_{max} = \frac{\sigma_{yt}}{2 \times SF} = \left[\frac{\sigma_1 - \sigma_2}{2}, \frac{\sigma_1}{2}, \frac{\sigma_2}{2}\right]$$

Using the following relation for σ_1 and σ_2,

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

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

$$= \frac{320}{2} \pm \sqrt{3600+6400}$$

$\sigma_{1,2} = 160 \pm 100$

$\sigma_1 = 160+100 = 260$ MPa

$\sigma_2 = 160-100 = 60$ MPa

$$\frac{\sigma_{yt}}{2\times SF} = \text{Max.}\left[\frac{260-60}{2}, \frac{260}{2}, \frac{60}{2}\right]$$

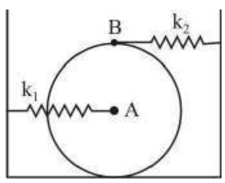
$= \text{Max.}[100, 130, 30]$

$$\frac{\sigma_{yt}}{2\times SF} = 130$$

$$SF = \frac{\sigma_{yt}}{2\times 130} = \frac{468}{260} = 1.8$$

43. (23.1) rad/s

Given data: For a uniform think disk,
mass $(m) = 1$ kg
radius $(r) = 0.1$ m
(By refer to Fig.) spring stiffnesses; $K_1 = 400$ N/m
$K_2 = 100$ N/m



Considering the following relation,

$\Sigma M_O = 0$

$I\ddot{\theta} + F_1(r\cos\theta) + F_2(2r\cos\theta) = 0$

Where,

$\therefore F_1 = K_1 r \sin\theta$

$F_2 = K_2 2r \sin\theta$

Assume

$\sin\theta = 0$

$\cos\theta = 1$

or, $I\ddot{\theta} + (K_1 r^2 + 4K_2 r^2)\theta = 0$

$I_{equivalent} = I_{mean} + mr^2$

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

$\therefore$ Natural frequency of vibration of the system,

$$\omega_n = \sqrt{\frac{k_1 r^2 + 4k_2 r^2}{\frac{3}{2}mr^2}}$$

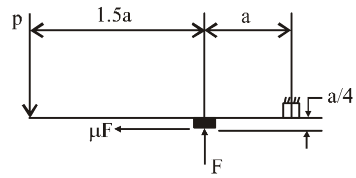
$$= \sqrt{\frac{(k_1+4k_2)r^2}{\frac{3}{2}mr^2}} = \sqrt{\frac{(400+4\times100)}{\frac{3}{2}\times(1)}}$$

$$= \sqrt{\frac{2(800)}{3}} = \sqrt{\frac{1600}{3}} = \sqrt{533.33} = 23.09$$

$\omega_n \approx 23.1$ rad/s

44. (212.5 mm)

Given data, torque capacity of brake,
$T = 25a$ Nm
Rotational speed of brake drum, N = 100 rpm
Coefficient of friction; $\mu = 0.25$
maximum actuating force, (P) = 2000N
Refer to Free Body diagram;



Now, considering the equilibrium, taking moment about fulcrum, $\Sigma M = 0$

$$F\times a + \mu F \times \frac{a}{4} - p\times(1.5a+a) = 0$$

or $$Fa + \frac{\mu Fa}{4} - p\times 2.5a = 0$$

$$Fa\left(1+\frac{\mu}{4}\right) - 2.5\,pa = 0 \qquad \text{...(i)}$$

Using the relation,

Torque, $T = (\mu F)\times a$

$250 = 0.25 \times F \times a$

$$Fa = \frac{250}{0.25} = 1000$$

Substituting the value of Fa in eqn. (i), we get

$$1000\left(1+\frac{0.25}{4}\right) - 2.5\times2000\times a = 0$$

$1000(1.0625) - 5000a = 0$

$5000a = 1062.5$

$$a = \frac{1062.5}{5000} = 0.2125$$

$a = 0.2125$m

$a \approx 212.5$ mm

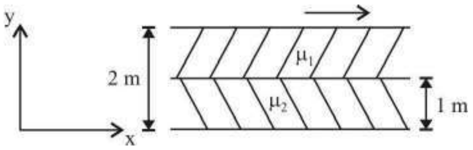
45. (1) m/s, Given data:

Velocity of upper moving plat $(v_m) = 3$ m/s

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

dynamic viscosity of lower fluid $= \mu_2$
dynamic viscosity of upper fluid $= \mu_1$
$\therefore \mu_2 = 2\mu_1$

Refer to figure given below:



Let, v_i = velocity of fluid at interface using the following relation,

$$\mu_1\left(\frac{v_m - v_i}{y}\right) = \mu_2\left(\frac{v_2 - v_f}{y}\right)$$

(Shear stress will be equal for both fixed and moving plates)

where, v_f = velocity of fixed plate

$y = 1$m

$$\therefore\ \mu_1\left(\frac{3 - v_i}{1}\right) = 2\mu_1\left(\frac{v_2 - 0}{1}\right)$$

or, $\mu_1(3 - v_i) = 2\mu_1(v_i)$

$3 - v_i = 3v_i$

$3v_i = 3$

$$v_i = \frac{3}{3} = 1 \text{ m/s}$$

46. (80 mm)

Given data: Side of cube (a) = 100mm = 0.1m

density of cube material, $P_c = 800$ kg/m^3

density of liquid (or water), $P_w = 1000$ kg/m^3

Let, $y_{min.}$ = minimum height to which the liquid needs to be poured into container

Volume of cube $(V_c) = a^3 = (0.1)^3 = 1 \times 10^{-3}$ m^3

Now, weight of cube, $(W_c) = P_c \times V_c \times g$

$= 800 \times 1 \times 10^{-3} \times 10$ $\quad [\because g = 10 \text{ m/s}^2]$

$= 8$N ...(i)

weight of liquid displaced, (w_L)

$= P_w \times V_L \times g$

where, V_L = Volume of liquid

$= a \times a \times y_{min.}$

$= 0.1 \times 0.1 \times y_{min.}$

$= 0.01\, y_{min.}$ m^3

$\therefore\ W_L = 1000 \times 0.01\, y_{min.} \times 10$

$W_L = 100 y_{min.}$ ...(ii)

Equating eqn. (i) and (ii), we get

$8 = 100\, y_{min.}$

$$y_{min.} = \frac{8}{100} = 0.08\text{m}$$

$y_{min.} = 80$ mm

47. (60ºC)

Given data: Internal heat generation,

$Q_g = 10000$ w/m^3

thickness of slabs, $t_A = t_B = t_C = 1$m

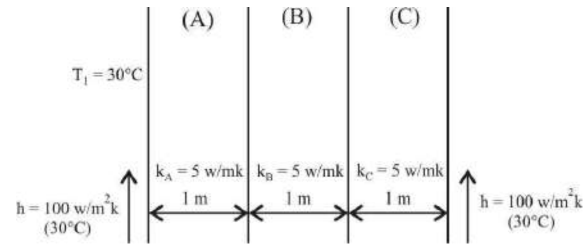
thermal conductivities for each slab,

$K_A = K_B = K_C = 5$w/mk

heat transfer coefficient, $h = 100$ w/m^2 k

Left slab temperature, $T_1 = 30$ºC

Refer to fig. given below



Heat lost by slab (A), $Q_A = \left[\dfrac{T_1 - 30}{\frac{l}{hA}}\right] = \dfrac{T_1 - 30}{\frac{1}{hA}}$

$= (T_1 - 30) \times hA$

Heat last by slab (C), $Q_C = \dfrac{T_2 - 30}{\frac{l}{hA}} = \dfrac{T_2 - 30}{\frac{1}{hA}}$

$= (T_2 - 30) \times hA$

where, A = cross-sectional area

Now, heat developed in the slab (B), $Q_B = Q_g \times V$

where, V = volume

$= A \times l = A \times 1$

$\therefore\ Q_B = 10000 \times A$

Now, using the following relation, we have

$Q_B = Q_A + Q_C$

$10000A = (T_1 - 30) \times hA + (T_2 - 30) \times hA$

or, $10000 = (T_1 - 30) \times h + (T_2 - 30) \times h$

or, $h[T_1 - 30 + T_2 - 30] = 10000$

or, $100[T_1 + T_2 - 60] = 10000$

or, $(100 + T_2 - 60) = 100$

or, $T_2 + 40 = 100$

or, $T_2 = 100 - 40$

$\therefore\ T_2 = 60$ºC

48. (83.14) pa.

Given data : capacity of rigid container (V)

$= 1000$ litres $= 1000 \times 10^{-3}$ m$^3 = 1$ m^3

Initial temperature, $T_1 = 27$ºC

$= 27 + 273 = 300$ K

Final temperature, $T_2 = 37$ºC

$= 37 + 273 = 310$ K

Let, ΔP = change in pressure of contained gas

R = 8.314 J/mol K (Given)

Using the following relation,

$V \cdot \Delta p = nR\Delta T$ (differentiating Ideal gas equation)

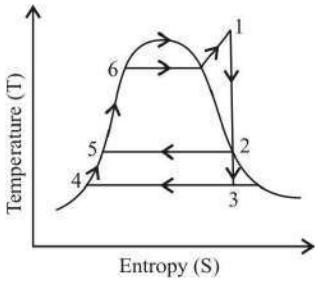
where, $\Delta T = T_2 - T_1 = 310 - 300 = 10$ K

$\therefore\ 1 \times \Delta p = 1 \times 8.314 \times 10$

$\Delta p = 83.14$ Pa

49. (20) %

Given data : Refer to figure given below:



Let, M_1 = mass flow rate of steam bled from turbine

M_2 = mass flow rate of steam going to condenser

$M_1 + M_2$ = total mass flow rate at inlet to turbine

Here, enthalpies at various states,

$H_1 = 3350$ kJ/kg, $H_2 = 2800$ kJ/kg, $H_3 = 2300$ kJ/kg

$H_4 = 175$ kJ/kg, $H_5 = 700$ kJ/kg, $H_6 = 1000$ kJ/kg

using the following relation,

$M_1H_4 + M_2H_2 = (M_1 + M_2) \times H_5$

or, $175\,M_1 + 2800\,M_2 = (M_1 + M_2) \times 700$

$175M_1 + 2800M_2 = 700\,M_1 + 700M_2$

$(700 - 175)M_1 = (2800 - 700)M_2$

$525M_1 = 2100M_2$

or, $\dfrac{M_1}{M_2} = \dfrac{2100}{525} = 4$

or, $\dfrac{M_1}{M_2} + 1 = 4 + 1$

or $\dfrac{M_1 + M_2}{M_2} = 5$

or, $\dfrac{M_2}{M_1 + M_2} = \dfrac{1}{5} = 0.20$

$\therefore \dfrac{M_2}{M_1 + M_2} \approx 20\%$

50. (51.23) %

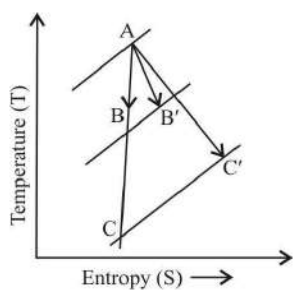
Given data: Refer to figure (T-S) graph:

Isentropic efficiency $(\eta_{isen.}) = 0.70$

Pressure ratio $(r_{p_1}) = \dfrac{P_A}{P_B} = 3$

$(r_{p_2}) = \dfrac{p_A}{p_C} = 5$

Specific heat ratio $(\gamma) = 1.4$



Using the following relation,

$W_{A-B} = mC_p(T_A - T_B)$

$= mC_p \times \eta_{isen.} \times (T_A - T_B)$

$$W_{A-B} = mC_p \times \eta_{A-B} \times \left[T_A - \frac{T_A}{(r_{p_1})^{\frac{\gamma-1}{\gamma}}}\right]$$

As we know that, $W_{A-B} = W_{A-C}$

$$\eta_{A-B} \times \left\{1 - \frac{1}{(r_{p_1})^{\frac{\gamma-1}{\gamma}}}\right\} = \eta_{A-C} \times \left\{1 - \frac{1}{(r_{p_2})^{\frac{\gamma-1}{\gamma}}}\right\}$$

Here, $\eta_{A-B} = \eta_{isec.} = 0.70$

$$\therefore\ 0.70 \times \left\{1 - \frac{1}{(3)^{\frac{1.4-1}{1.4}}}\right\} = \eta_{A-C} \times \left\{1 - \frac{1}{(5)^{\frac{1.4-1}{1.4}}}\right\}$$

$$0.70 \times \left\{1 - \frac{1}{(3)^{0.4/1.4}}\right\} = \eta_{A-C} \times \left\{1 - \frac{1}{(5)^{\frac{0.4}{1.4}}}\right\}$$

$$0.70 \times \left\{1 - \frac{1}{(3)^{0.286}}\right\} = \eta_{A-C} \times \left\{1 - \frac{1}{(5)^{0.286}}\right\}$$

On solving above, we have

$\eta_{A-C} = 0.5123$ or 51.23%

51. (2.10)

52. (3.74) μm

Given data :

Side cutting edge angle, $\theta_s = 45°$

End cutting edge angle, $\theta_e = 10°$

feed rate, $f = 0.1$ mm/rev.

$\therefore$ centre line average surface roughness (R_S)

$$R_S = \frac{f}{4(\tan\theta_s + \cot\theta_c)}$$

$$= \frac{0.1}{4\,(\tan 45° + \cot 10°)}$$

$$R_s = \frac{0.1}{4\,(1 + 5.672)} = \frac{0.1}{4 \times 6.672}$$

$R_s \approx 3.747 \times 10^{-3}$ μm

$R_s \approx 3.74$ mm

53. (40.3 m/min.)

Given data :

Taylor's Tool life Equation,

$VT^n = C$

where, V = velocity (m/min.)

T = time (min.)

For tool X, $n = 0.3$, $C = 60$

For tool Y, $n = 0.6$, $C = 90$

$\therefore$ For tool X, $V_1T_1^{0.3} = 60$ ...(i)

For tool Y, $V_2 T_2^{0.6} = 90$ ...(ii)

Dividing Eqn. (ii) by Eqn. (i), we have,

$$\frac{V_2 T_2^{0.6}}{V_1 T_1^{0.3}} = \frac{90}{60} = 1.5$$

For same tool life, $V_1 = V_2 = V, T_1 = T_2 = T$

$$\frac{VT^{0.6}}{VT^{0.3}} = 1.5$$

$$T^{(0.6-0.3)} = 1.5 \Rightarrow T^{0.3} = 1.5$$

$T = (1.5)^{1/0.3} = 3.86$

Substituting the value of T in eqn. (i), we have

$V \times (3.86)^{0.3} = 60$

$$V = \left[\frac{60}{(3.86)^{0.3}}\right] = \frac{60}{1.49} = 40.27$$

$V \approx 40.3$ m/min.

54. (146 min.)

Given data :

	M_1	M_2	M_3	M_4	M_5
J_1	40	30	50	50	58
J2	26	38	60	26	38
J3	40	34	28	24	30
J_4	28	40	40	32	48
J_5	28	32	38	22	44

Row minimization matrix,

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

Column minimization matrix:

14	0	22	28	28
0	8	32	4	8
14	4	0	2	0
2	10	12	10	18
2	2	10	0	14

After covering zeros in rows and columns

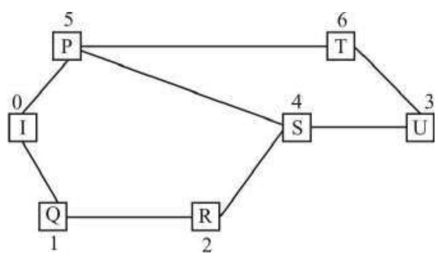
16	[0]	16	26	22
~~0~~	6	24	~~0~~	[0]
[0]	4	2	6	8
4	6	6	[0]	10

optimum values for assignment

$J_1 - M_2$	$J_2 - M_5$	$J_3 - M_3$	$J_4 - M_1$	$J_5 - M_4$
↓	↓	↓	↓	↓
30	38	28	28	22

Minimum value of time = 30 + 38 + 28 + 28 + 22
= 146 mins.

55. (6) weeks: The network flow diagram is given as :



Total duration of project completion (T_1) = 14 weeks

Total float $(T_2) = 11 - 5 - 4 = 2$ weeks

Maximum duration of activity 5 without delaying the completion of project = 2 + 4 = 6 weeks

GATE MECHANICAL ENGINEERING SOLVED PAPER

2019 Set-2

Duration: 3 hrs **Maximum Marks: 100**

INSTRUCTIONS

1. There are a total of 65 questions carrying 100 marks.
2. The subject specific GATE paper section consists of 55 questions. The GA section consists of 10 questions.
3. Questions are of Multiple Choice Question (MCQ) or Numerical Answer type. A multiple choice question will have four choices for the answer with only one correct choice. For numerical answer type questions, the answer is a number and no choices will be given.
4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions will result in NEGATIVE marks. For all 1 mark questions, $\frac{1}{3}$ mark will be deducted for each wrong answer. For all 2 marks questions, $\frac{2}{3}$ mark will be deducted for each wrong answer.
5. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE.**

GENERAL APTITUDE TEST

QUESTIONS 1 TO 5 CARRY ONE MARK EACH

1. Once the team of analysts identify the problem, we _____ in a better position to comment on the issue.
Which one of the following choices CANNOT fill the given blank?
(a) will be (b) were to be
(c) are going to be (d) might be

2. A final examination is the _____of a series of evaluations that a student has to go through.
(a) culmination (b) consultation
(c) desperation (d) insinuation

3. If IMHO = JNIP; IDK = JEL; and SO = TP, then IDC = _____
(a) JDE (b) JED
(c) JDC (d) JCD

4. The product of three integers X, Y and Z is 192. Z is equal to 4 and P is equal to the average of X and Y. What is the minimum possible value of P?
(a) 6 (b) 7
(c) 8 (d) 9.5

5. Are there enough seats here? There are _______ people here than I expected.
(a) many (b) most
(c) least (d) more

QUESTIONS 6 TO 10 CARRY TWO MARKS EACH

6. Fiscal deficit was 4% of the GDP in 2015 and that increased to 5% in 2016. If the GDP increased by 10% from 2015 to 2016, the percentage increase in the actual fiscal deficit is ______
(a) 37.50 (b) 35.70
(c) 25.00 (d) 10.00

7. Two pipes P and Q can fill a tank in 6 hours and 9 hours respectively, while a third pipe R can empty the tank in 12 hours. Initially, P and R are open for 4 hours. Then P is closed and Q is opened. After 6 more hours R is closed. The total time taken to fill the tank (in hours) is _______
(a) 13.50 (b) 14.50
(c) 15.50 (d) 16.50

8. While teaching a creative writing class in India, I was surprised at receiving stories from the students that were all set in distant places; in the American West with cowboys and in Manhattan penthouses with clinking ice cubes. This was, till an eminent Caribbean writer gave the writers in the once-colonised countries the confidence to see the shabby lives around them as worthy of being "told".
The writer of this passage is surprised by the creative writing assignments of his students, because ______
(a) Some of the students had written stories set in foreign places

(b) None of the students had written stories set in India
(c) None of the students had written about ice cubes and cowboys
(d) Some of the students had written about ice cubes and cowboys

9. Mola is a digital platform for taxis in a city. It offers three types of rides -Pool, Mini and Prime. The Table below presents the number of rides for the past four months. The platform earns one US dollar per ride. What is the percentage share of revenue contributed by Prime to the total revenues of Mola, for the entire duration?

Type	Month			
	January	February	March	April
Pool	170	320	215	190
Mini	110	220	180	70
Prime	75	180	120	90

(a) 16.24 (b) 23.97
(c) 25.86 (d) 38.74

10. X is an online media provider. By offering unlimited and exclusive online content at attractive price for a loyalty membership, X is almost forcing its customers towards its loyalty membership. If its loyalty membership continues to grow at its current rate, within the next eight years more households will be watching X than cable television.

Which one of the following statements can be inferred from the above paragraph?
(a) Most households that subscribe to X's loyalty membership discontinue watching cable television
(b) Non-members prefer to watch cable television
(c) Cable television operators don't subscribe to X's loyalty membership
(d) The X is cancelling accounts of non-members

TECHNICAL SECTION TEST

QUESTIONS 1 TO 25 CARRY ONE MARK EACH

1. In matrix equation $[A]\{X\} = \{R\}$,

$$[A]=\begin{bmatrix}4 & 8 & 4\\ 8 & 16 & -4\\ 4 & -4 & 15\end{bmatrix}, \{X\}=\begin{Bmatrix}2\\1\\4\end{Bmatrix} \text{ and } \{R\}\begin{Bmatrix}32\\16\\64\end{Bmatrix}$$

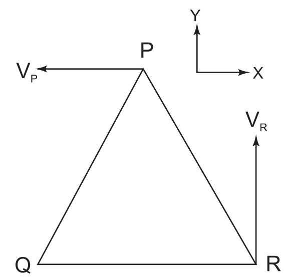
One of the eigenvalues of matrix $[A]$ is
(a) 4 (b) 8
(c) 15 (d) 16

2. The directional derivative of the function $f(x,y) = x^2 + y^2$ along a line directed from (0,0) to (1,1), evaluated at the point $x = 1, y = 1$ is
(a) $\sqrt{2}$ (b) 2
(c) $2\sqrt{2}$ (d) $4\sqrt{2}$

3. The differential equation $\frac{dy}{dx} + 4y = 5$ is valid in the domain $0 \le x \le 1$ with $y(0) = 2.25$. The solution of the differential equation is
(a) $y = e^{-4x} + 5$ (b) $y = e^{-4x} + 1.25$
(c) $y = e^{4x} + 5$ (d) $y = e^{4x} + 1.25$

4. An analytic function $f(z)$ of complex variable $z = x + i\,y$ may be written as $f(z) = u(x, y) + i\,v(x, y)$. Then $u(x, y)$ and $v(x,y)$ must satisfy
(a) $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$
(b) $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$
(c) $\frac{\partial u}{\partial x} = -\frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = \frac{\partial v}{\partial x}$
(d) $\frac{\partial u}{\partial x} = -\frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$

5. A rigid triangular body, POR, with sides of equal length of 1 unit moves on a flat plane. At the instant shown, edge OR is parallel to the x-axis, and the body moves such that velocities of points P and R are V_P and V_R, in the x and y directions, respectively. The magnitude of the angular velocity of the body is



(a) $2V_R$ (b) $2V_P$
(c) $V_R/\sqrt{3}$ (d) $V_P/\sqrt{3}$

6. Consider a linear elastic rectangular thin sheet of metal, subjected to uniform uniaxal tensile stress if 100 MPa along the length direction. Assume plane stress conditions in the plane normal to the thickness. The Young's modulus E = 200 MPa and Poisson's ratio v = 0.3 are given. The principal strains in the plane of the sheet are
(a) (0.35, – 0.15) (b) (0.5, 0.0)
(c) (0.5, – 0.15) (d) (0.5, – 0.5)

7. A spur gear has pitch circle diameter D and number of teeth T, The circular pitch of the gear is
(a) $\frac{\pi D}{T}$ (b) $\frac{T}{D}$
(c) $\frac{D}{T}$ (d) $\frac{2\pi D}{T}$

8. Endurance limit of a beam subjected to pure bending decreases with
(a) decrease in the surface roughness and decrease in the size of the beam
(b) increase in the surface roughness and decrease in the size of the beam
(c) increase in the surface roughness and increase in the size of the beam
(d) decrease in the surface roughness and increase in the size of the beam

9. A two-dimensional incompressible frictionless flow field is given by $\vec{u} = x\hat{i} - y\hat{j}$ If ρ is the density of the fluid, the expression for pressure gradient vector at any point in the flow field is given as

(a) $\rho(x\hat{i} + y\hat{j})$ (b) $-\rho(x\hat{i} + y\hat{j})$

(c) $\rho(x\hat{i} - y\hat{j})$ (d) $-\rho(x^2\hat{i} + y^2\hat{j})$

10. Sphere 1 with a diameter of 0.1 m is completely by another sphere 2 of diameter 0.4 m. The view factor F_{12} is

(a) 0.0625 (b) 0.25
(c) 0.5 (d) 1.0

11. One-dimensional steady state heat conduction takes place through a solid whose cross-sectional area varies linearly in the direction of heat transfer. Assume there is no heat generation in the solid and the thermal conductivity of the material is constant and independent of temperature. The temperature distribution in the solid is

(a) Linear (b) Quadratic
(c) Logarithmic (d) Exponential

12. For a simple compressible system, v, s, p and T are specific volume, specific entropy, pressure and temperature, respectively. As per Maxwell's relations, $\left(\frac{\partial v}{\partial s}\right)_p$ is equal to

(a) $\left(\frac{\partial s}{\partial T}\right)_p$ (b) $\left(\frac{\partial p}{\partial v}\right)_T$

(c) $-\left(\frac{\partial T}{\partial v}\right)_p$ (d) $\left(\frac{\partial T}{\partial p}\right)_s$

13. Which one of the following modifications of the simple ideal Rankine cycle increases the thermal efficiency and reduces the moisture content of the steam at the turbine outlet?

(a) Increasing the boiler pressure
(b) Decreasing the boiler pressure
(c) Increasing the turbine inlet temperature
(d) Decreasing the condenser pressure

14. Harden ability of steel is a measure of

(a) the ability to harden when it is cold worked
(b) the maximum hardness that can be obtained when it is austenitized and then quenched
(c) the depth to which required hardening is obtained when it is austenitized and then quenched
(d) the ability to retain its hardness when it is heated to elevated temperatures

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

(a) viscosity (b) surface tension
(c) freezing range (d) degree of superheat

16. The cold forming process in which a hardened tool is pressed against a workpiece (when there is relative motion between the tool and the workpiece) to produce a roughened surface with a regular pattern is

(a) Roll forming (b) Strip rolling
(c) Knurling (d) Cham fering

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

(a) Snap gage (b) Ring gage
(c) Plug gage (d) Master gage

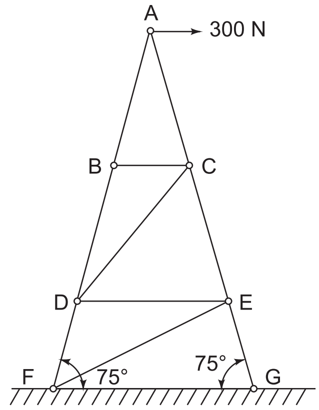
18. The transformation matrix for mirroring a point in $x - y$ plane about the line $y = x$ is given by

(a) $\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ (b) $\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$

(c) $\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$ (d) $\begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix}$

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

20. The figure shows an idealized plane truss. If a horizontal force of 300 N is applied at point A, then the magnitude of the force produced in member CD is ______N.

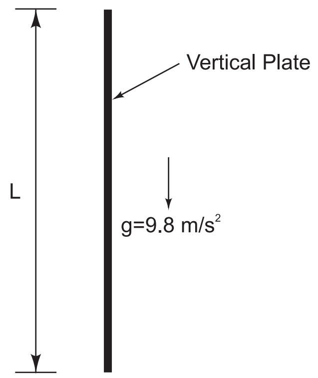


21. The state of stress at a point in a component is represented by a Mohr's circle of radius 100 MPa centered at 200 MPa on the normal stress axis. On a plane passing through the same point the normal stress is 260 MPa. The magnitude of the shear stress on the same plane at the same point is ____ MPa.

22. A wire of circular cross-section of diameter 1.0 mm is bent into a circular arc of radius 1.0 m by application of pure bending moments at its ends. The Young's modulus of the material of the wire is 100 GPa. The maximum tensile stress developed in the wire is ____ MPa.

23. Water enters a circular pipe of length L = 5.0 m and diameter D = 0.20 m with Reynolds number R_{eD} = 500. The velocity profile at the inlet of the pipe is uniform while it is parabolic at the exit. The Reynolds number at the exit of the pipe is _____

24. A thin vertical flat plate of height L, and infinite width perpendicular to the plane of the figure, is losing heat to the surroundings by natural convection. The temperatures of the plate and the surroundings, and the properties of the surrounding fluid, are constant. The relationship between the average Nusselt and Rayleigh numbers is given as $Nu = KRa^{1/4}$, where K is a constant. The length scales for Nusselt and Rayleigh numbers are the height of the plate. The height of the plate is increased to $16L$ keeping all other factors constant.



If the average heat transfer coefficient for the first plate is h_1 and that for the second plate is h_2, the value of the ratio h_1/h_2 is _______.

25. In an electrical discharge machining process, the break down voltage across inter electrode gap (IEG) is 200 V and the capacitance of the RC circuit is 50μF. The energy (in J) released per spark across the IEG is _______.

QUESTIONS 26 TO 55 CARRY TWO MARKS EACH

26. Given a vector $\vec{u} = \frac{1}{3}\left(-y^3\hat{i} + x^3\hat{j} + z^3\hat{k}\right)$ and $\hat{n}$ as the unit normal vector to the surface of the hemisphere ($x^2 + y^2 + z^2 = 1$; $z \geq 0$) the value of integral $\int(\nabla \times \vec{u}) \cdot \hat{n}\, dS$ evaluated on the curved surface of the hemisphere S is

(a) $-\frac{\pi}{2}$ (b) $\frac{\pi}{3}$

(c) $\frac{\pi}{2}$ (d) π

27. A differential equation is given as

$$x^2\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = 4$$

The solution of the differential equation in terms of arbitrary constants C_1 and C_2 is

(a) $y = C_1 x^2 + C_2 x + 2$ (b) $y = \frac{C_1}{x^2} + C_2 x + 2$

(c) $y = C_1 x^2 + C_2 x + 4$ (d) $y = \frac{C_1}{x^2} + C_2 x + 4$

28. The derivative of $f(x) = \cos(x)$ can be estimated using the approximation

$$f'(x) = \frac{f(x+h) - f(x-h)}{2h}$$. The percentage error is calculated as

$$\left(\frac{\text{Exact value} - \text{Approximate value}}{\text{Exact value}}\right) \times 100 \cdot$$

The percentage error in the derivative of $f(x)$ at $x = \pi/6$ radian choosing $h = 0.1$ radian is

(a) < 0.1% (b) > 0.1% and <1%

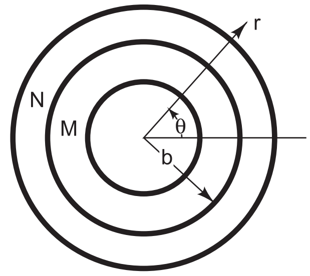
(c) >1% and >5% (d) > 5%

29. A ball of mass 3 kg moving with a velocity of 4m/s undergoes a perfectly-elastic direct-central impact with a stationary ball of mass m. After the impact is over, the kinetic energy of the 3 kg ball is 6J. The possible value (s) of m is/are

(a) 1 kg only (b) 6 kg only

(c) 1 kg, 6kg (d) 1 kg 9 kg

30. Consider two concentric circular cylinders of different materials M and N in contact with each other at $r = b$, as shown below. The interface at $r = b$ is frictionless. The composite cylinder system is subjected to internal pressure P. Let $\left(u_r^M, u_\theta^M\right)$ and $\left(\sigma_{rr}^M, \sigma_{\theta\theta}^M\right)$ denote the radial and tangential displacement and stress components, respectively, in material M. Similarly, $\left(u_r^N, u_\theta^N\right)$ and $\left(\sigma_{rr}^N, \sigma_{\theta\theta}^N\right)$ denote the radial and tangential displacement and stress components, respectively, in material N. The boundary conditions that need to be satisfied at the frictionless interface between the two cylinders are:



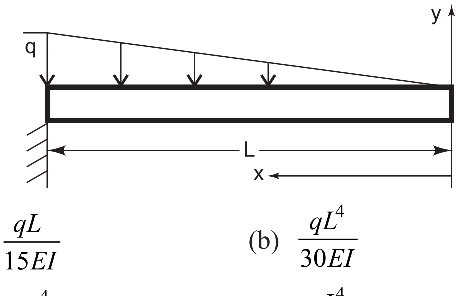
(a) $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$ only

(b) $u_r^M = u_r^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$ *and* $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$

(c) $u_\theta^M = u_\theta^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only

(d) $\sigma_{rr}^M = \sigma_{rr}^N$ and $\sigma_{\theta\theta}^M = \sigma_{\theta\theta}^N$ only

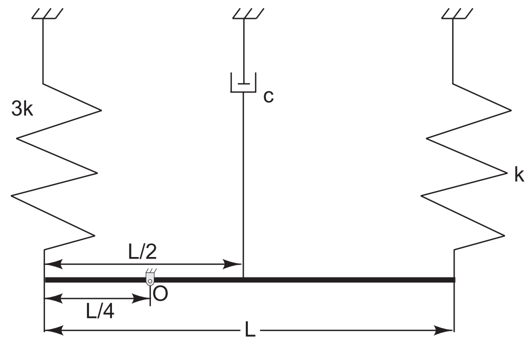
31. A prismatic,straight elastic, cantilever beam is subjected to a linearly distributed transverse load as shown below. If the beam length is L Young's modulus E, and area moment of inertia I, the magnitude of the maximum deflection is



(a) $\frac{qL}{15EI}$ (b) $\frac{qL^4}{30EI}$

(c) $\frac{qL^4}{10EI}$ (d) $\frac{qL^4}{60EI}$

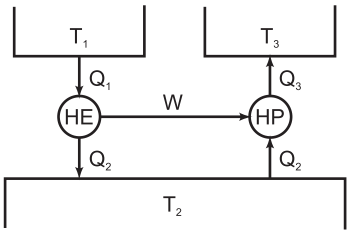
32. A slender uniform rigid bar of mass m is hinged at O and supported by two springs with stiffnesses $3k$ and k, and a damper with damping coefficient C, as shown in the figure. For the system to be critically damped, the ratio $C/\sqrt{km}$ should be



(a) 2 (b) 4

(c) $2\sqrt{7}$ (d) $4\sqrt{7}$

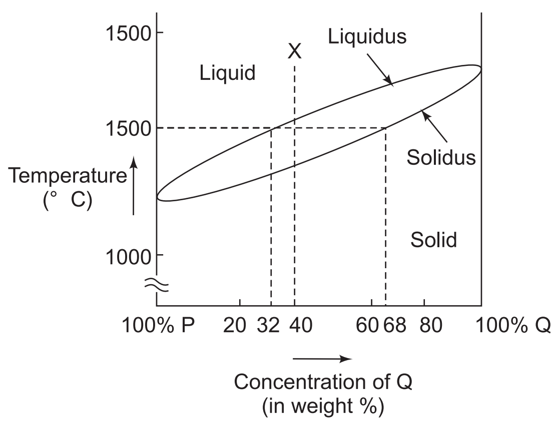
33. The figure shows a heat engine (HE) working between two reservoirs. The amount of heat (Q_2) rejected by the heat engine is drawn by a heat pump (HP). The heat pump receives the entire work output (W) of the heat engine. If temperatures, $T_1 > T_3 > T_2$, then the relation between the efficiency (η) of the heat engine and the coefficient of performance (COP) of the heat pump is



(a) COP = η (b) COP = 1 + η

(c) COP = η^{-1} (d) COP = $\eta^{-1} - 1$

34. The binary phase diagram of metals P and Q is shown in the figure. An alloy X containing 60% P and 40% Q (by weight) is cooled from liquid to solid state. The fractions of solid and liquid (in weight percent) at 1250°C, respectively, will be



(a) 77.8% and 22.2% (b) 22.2% and 77.8%

(c) 68.0% and 32.0% (d) 32.0% and 68.0%

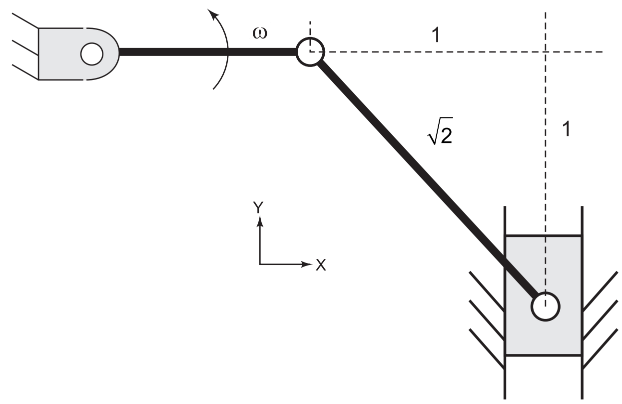
35. The activities of a project their duration and the precedence relationships are given in the table. For example in a precedence relationship "X < Y, Z" means that X is predecessor of activities Y and Z. The time to complete the activities along the critical path is _____ weeks.

Activity	Duration(Weeks)	Precedence Relationship
A	5	A< B, C, D
B	7	B > E, F, G
C	10	C < 1
D	6	D < G
E	3	E < H
F	9	F < I
G	7	G < I
H	4	H < 1
I	2	----

(a) 17 (b) 21

(c) 23 (d) 25

36. The crank of a slider-crank mechanism rotates counter-clockwise (CCW) with a constant angular velocity ω as shown Assume the length of the crank to be r

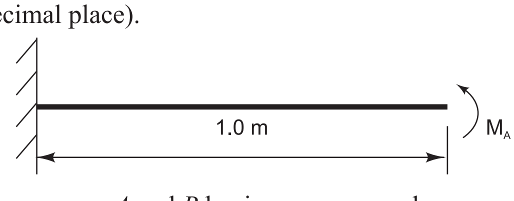


Using exact analysis, the acceleration of the slider in the y-direction, at the instant shown, where the crank is parallel to x-axis is given by

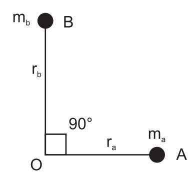
(a) $-\omega^2 r$ (b) $2\omega^2 r$

(c) $\omega^2 r$ (d) $-2\omega^2 r$

37. A horizontal cantilever beam of circular cross-section, length 1.0 m and flexural rigidity EI = 200 N.m^2 is subjected to an applied moment M_A = 1.0N.m at the free end as shown in the figure. The magnitude of the vertical deflection of the free end is _____ mm (round off to one decimal place).



38. Two masses A and B having mass m_a and m_b, respectively, lying in the plane of the figure shown are rigidly attached to a shaft which revolves about an axis through O perpendicular to the plane of the figure. The radii of rotation of the masses m_a and m_b are r_a and r_b, respectively. The angle between lines OA and OB is 90°. If m_a = 10 kg, m_b = 20 kg, r_a = 200 mm and r_b = 400 mm, then the balance mass to be placed at a radius of 200 mm is ____kg (round off to two decimal places).

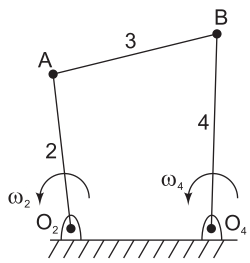


39. A four bar mechanism is shown in the figure. The link numbers are mentioned near the links. Input link 2 is rotating anticlockwise with a constant angular speed ω_2. Length of different links are:

$O_2O_4 = O_2A = L$

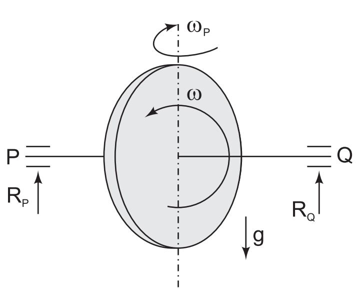
$AB = O_4B = \sqrt{2L}$.

The magnitude of the angular speed of the output link 4 is ω_4 at the instant when link 2 makes an angle of 90° with O_2O_4 as shown. The ratio $\frac{\omega_4}{\omega_2}$ is ____ (round off to two decimal places).

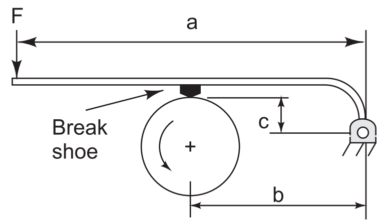


40. The probability that a part manufactured by a company will be defective is 0.05. If 15 such parts are selected randomly and inspected, then the probability that at least two parts will be defective is _____ (round off to two decimal places).

41. A uniform disc with radius r and a mass of m kg is mounted centrally on a horizontal axle of negligible mass and length of 1.5r. The disc spins counter-clockwise about the axle with angular speed ω, when viewed from the right-hand side bearing, Q. The axle precesses about a vertical axis at $\omega_p = \omega/10$ in the clockwise direction when viewed from above. Let R_P and R_Q (positive upwards) be the resultant reaction forces due to the mass and the gyroscopic effect, at bearings P and Q, respectively. Assuming $\omega^2 r = 300$ m/s^2 and $g = 10$ m/s^2 the ratio of the larger to the smaller bearing reaction force (considering appropriate signs) is ___



42. A short shoe external drum brake is shown in the figure. The diameter of the brake drum is 500 mm, The dimensions a = 1000 mm, b = 500 mm and c = 200 mm. The coefficient of friction between the drum and the shoe is 0.35. The force applied on the lever F = 100 N as shown in the figure. The drum is rotating anti-clockwise. The braking torque on the drum is _____ N. m. (round of to two decimal places).



43. Water flows through two different pipes **A** and **B** of the same circular cross-section but at different flow rates. The length of pipe **A** is 1.0 m and that of pipe **B** is 2.0 m. The flow in both the pipes is laminar and fully developed. If the frictional head loss across the length of the pipes is same, the ratio of volume flow rates Q_B/Q_A is ____ (round off to two decimal places).

44. The aerodynamic drag on a sports car depends on its shape. The car has a drag coefficient of 0.1 with the windows and the roof closed. With the windows and the roof open, the drag coefficient becomes 0.8. The car travels at 44 km/h with the windows and roof closed. For the same amount of power needed to overcome the aerodynamic drag, the speed of the car with the windows and roof open (round off to two decimal places), is ______ km/h (The density of air and the frontal area may be assumed to be constant).

45. Three sets of parallel plates LM, NR and PQ are given in figures 1, 2 and 3. The view factor F_{IJ} is defined as the fraction of radiation leaving plate I that is intercepted by plate J. Assume that the values of F_{LM} and F_{NR} are 0.8 and 0.4, respectively. The value of F_{PQ} (round off to one decimal places) is ______

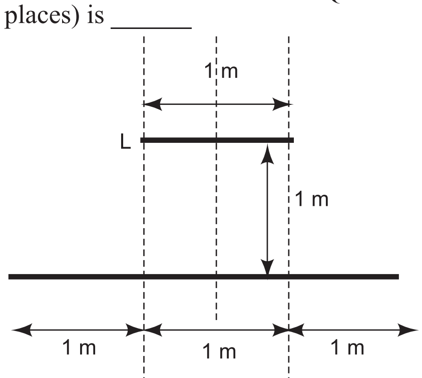


Figure 1

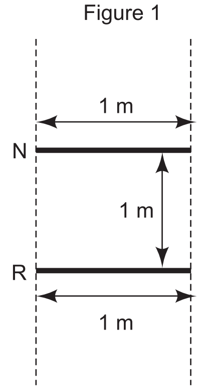


Figure 2

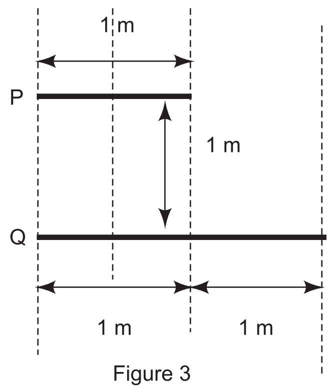


Figure 3

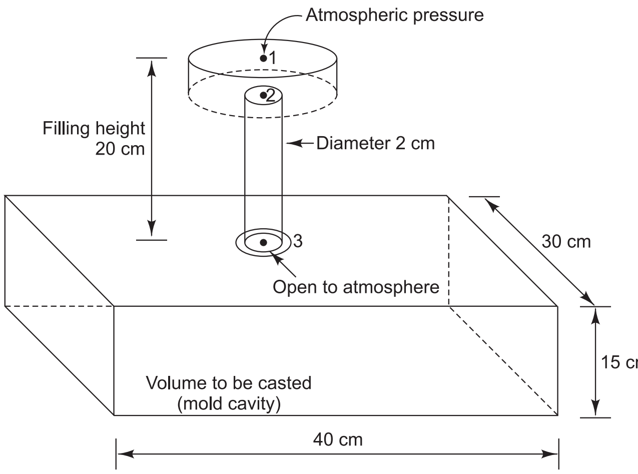
46. Hot and cold fluids enter a parallel flow double tube heat exchanger at 100°C and 15°C, respectively. The heat capacity rates of hot and cold fluids are C_h = 2000 W/K and C_c = 1200 W/K, respectively. If the outlet temperature of the cold fluid is 45°C, the log mean temperature difference (LMTD) of the heat exchanger is ______ K (round off to two decimal places).

47. Water flowing at the rate of 1 kg/s through a system is heated using an electric heater such that the specific enthalpy of the water increases by 2.50 kJ/kg and the specific entropy increases by 0.007 kJ/kg. K. The power input to the electric heater is 2.50 kW. There is no other work or heat interaction between the system and the surroundings. Assuming an ambient temperature of 300 K, the irreversibility rate of the system is ____ kW (round off to two decimal places)

48. An idealized centrifugal pump (blade outer radius of 50 m m) consumes 2 kW power while running at 3000 rpm. The entry of the liquid into the pump is axial and exit from the pump is radial with respect to impeller. If the losses are neglected, then the mass flow rate of the liquid through the pump is ______ kg/s (round off to two decimal places).

49. An air standard Otto cycle has thermal efficiency of 0.5 and the mean effective pressure of the cycle is 1000 kPa. For air, assume specific heat ratio γ = 1.4 and specific gas constant R = 0.287 kJ/kg. K. If the pressure and temperature at the beginning of the compression stroke are 100 kPa and 300K, respectively, then the specific net work output of the cycle is ______ kJ/kg (round off to two decimal places).

50. The figure shows a pouring arrangement for casting of a metal block. Frictional losses are negligible. The acceleration due to gravity is 9.81 m/s^2. The time (in s, round off to two decimal places) to fill up the mold cavity (of size 40 cm × 30 cm × 15 cm) is _____



51. A gas tungsten arc welding operation is performed using a current of 250 A and an arc voltage of 20V at a welding speed of 5 m m/s. Assuming that the arc efficiency is 70%, the net heat input per unit length of the weld will be ______ kJ/mm (round off to one decimal place).

52. The thickness of a sheet is reduced by rolling (without any change in width) using 600 mm diameter rolls. Neglect elastic deflection of the rolls and assume that the coefficient of friction at the roll-workpiece interface is 0.05. The sheet enters the rotating rolls unaided. If the initial sheet thickness is 2 mm, the minimum possible final thickness that can be produced by this process in a single pass is ____ mm (round off two decimal places).

53. A through hole is drilled in an aluminum alloy plate of 15 mm thickness with a drill bit of diameter 10 mm, at a feed of 0.25 mm/rev and a spindle speed of 1200 rpm. If the specific energy required for cutting this material is 0.7 N.m/mm^3, the power required for drilling is _____ W (round off to two decimal places)

54. In an orthogonal machining with a single point cutting tool of rake angle 10°, the uncut chip thickness and the chip thickness are 0.125 mm and 0.22 mm, respectively. Using Merchant's first solution for the condition of minimum cutting force, the coefficient of friction at the chip-tool interface is ______ (round off to two decimal places).

55. The annual demand of valves per year in a company is 10.000 units. The current order quantity is 400 valves per order. The holding cost is Rs. 24 per valve per year and the ordering cost is Rs. 400 per order. If the current order quantity is changed to Economic Order Quantity, then the saving in the total cost of inventory per year will be Rs. ____ (round off to two decimal places).

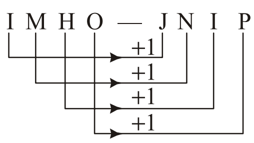
HINTS & SOLUTIONS

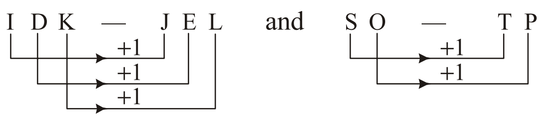
GENERAL APTITUDE TEST

1. **(b)** Since the sentence is in present tense, 'were to be' won't make the sentence grammatically correct because it is in past tense. Hence, the correct answer is option (b).

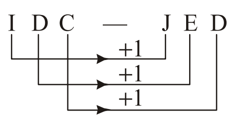
2. **(a)** 'Culmination' which means 'the highest point of something, especially as attained after a long time' fits correctly in the context of the sentence. Rest of the words are irrelevant. Therefore, the correct answer is option (a).

3. **(b)**





Similarly,



4. **(b)** $XYZ = 192$

$XY(4) = 192 \rfloor X4 = 48.$

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

We know that A.M. $\geq$ G.M.

$\frac{X+4}{2} \geq \sqrt{XY}$

$P \geq \sqrt{48}$

$\therefore \quad P = 7$

5. **(d)** In the sentence, there is a companion between the reality and expectation. Therefore, the sentence will take the comparative degree of adjective; 'more' is used when two things are compared.

6. **(a)** Let the G.D.P. in 2015 is ₹100

then Fiscal deficit in 2015 $= 100 \times \frac{4}{100} =$ ₹4.

G.D.P. in 2016 $= 100 \times \frac{110}{100} = 110.$

Fiscal deficit in 2016

$= 110 \times \frac{5}{100} = 5.5.$

Percentage increase in fiscal deficit

$= \left(\frac{5.5-4}{4}\right) \times 100 = 37.5\%$

7. **(b)** Portion of the tank filled by P and R in 4 hours

$= 4\left(\frac{1}{6} - \frac{1}{12}\right) = \frac{1}{3}$

Portion of the tank filled by Q and R in 6 hours

$= 6\left(\frac{1}{9} - \frac{1}{12}\right) = \frac{1}{6}$

Time taken to fill $\left(\frac{1}{3} + \frac{1}{6}\right)$ tank $= 4 + 6 = 10$ hours

So, in 10 hours, portion of the tank filled

$= \frac{1}{3} + \frac{1}{6} = \frac{1}{2}$ tank.

Time required to fill $\frac{1}{2}$ tank by pipe Q

$= 9 \times \frac{1}{2} = 4.5$ hours.

8 **(b)**

9. **(b)** Revenue collected by prime for the entire duration $= 75 + 180 + 120 + 90 = 465.$

Total revenue collected by Mola for the entire duration $= 1940$

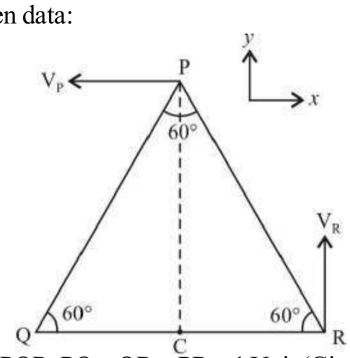
Hence, required percent $= \frac{465}{1940} \times 100 = 23.97\%$

10. **(a)**

TECHNICAL ABILITY TEST

1. **(d)** 2 **(c)** 3 **(b)** 4. **(b)**

5. **(a)** Given data:



In ΔPQR, PQ = QR = PR = 1 Unit (Given)

$\therefore \Delta$ PQR is an equilateral triangle

Now, using the following relation,

$V_R = r \cdot w$

where, V_R = linear velocity at point 'R'

r = radius = ½ unit

w = angular velocity

$V_R = \frac{1}{2} \times w$

$w = 2V_R$

6. **(c)** Given data : Tensile stress $(\sigma_x) = 100$ MPa

Young's Modulur (E) = 200 MPa

Poisson's ratio $(v) = 0.3$

Using the following relation

$$\Sigma_{xx} = \frac{\sigma_x}{E} - v\frac{\sigma_y}{E} = \frac{100}{200} - (0.3)\frac{0}{200}$$

$$\Sigma_{xx} = \frac{100}{200} = 0.5$$

$$\Sigma_{yy} = \left[\frac{\sigma_y}{E} - v\frac{\sigma_x}{E}\right] = \left[\frac{0}{200} - 0.3\times\frac{100}{200}\right]$$

$$= -\frac{0.3}{2} = -0.15$$

$\therefore$ Principal strainer in the plane of sheet are $(0.5, -0.15)$.

7. (a) A circular pitch is defined or the width of a tooth and a space, determined on the pitch circle.

$$P = \frac{\pi D}{T}$$

where, P = circular pitch
D = Pitch circle diameter
T = Number of teeth.

8. (c) Endurance limit of a beam subjected to pure binding decreases with increase in the surface roughness and increase in the size of the beam.

9. (b) **Given data :** For a two dimensional incompressible frictionless flow field.
$u = xi - yj$
Components of velocities
In x-direction $\Rightarrow u = x$
In y-direction $\Rightarrow v = -y$
using Navier-Stokes Equation,

$$P\frac{d\vec{v}}{dt} = -\tilde{N}\vec{P}$$

The above relation holds good for incompressible, frictionless fluid flow having no components of body forcess,

$\therefore$ Here, $\tilde{N}\vec{P}$ = Pressue gradient vector

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

$$\because \quad \tilde{N}\vec{P} = -P\left[\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right)\hat{i} + \left(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right)\hat{j}\right]$$

Now, $\frac{\partial u}{\partial x} = 1, \frac{\partial u}{\partial y} = 0$

$\frac{\partial v}{\partial x} = 0, \frac{\partial v}{\partial y} = -1$

$$\therefore \tilde{N}\vec{P} = -P[\{x(1) - y(0)\}i + \{x(0) + (-y)(-1)j]$$
$$= -P[x\hat{i} + y\hat{i}]$$

10. (d) Given data :
Diameter of sphere I, $D_1 = 0.1$m
Diameter of sphere II, $D_2 = 0.4$m
Using the following relation,
$F_{1-1} + F_{1-2} = 1$
$0 + F_{1-2} = 1 \Rightarrow F_{1-2} = 1 \qquad [\because F_{11} = 0]$

11. (c) For one dimensional steady state heat conduction,

$$Q = -KA\frac{dT}{dx}$$

For no heat generation

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

or, $-KA\frac{dT}{dx} = C_1$

$$dT = \frac{-C_1}{KA}dx$$

Integrating on both sides,

$$\int_1^2 dT = \int_1^2 \frac{-C_1}{KA}dx = \int_1^2 \frac{-C_1}{K(Dx+E)}dx$$

$$= \frac{-C_1}{K}\int_1^2 \frac{1}{(Dx+E)}dx$$

$$(T_2 - T_1) = \frac{-C_1}{K}\log_e\left(\frac{Dx_2 + E}{Dx_1 + E}\right)$$

Hence, temperature distribution in the solid in logarithimic

12. (d) Given data :
For a simple compressible system
V = Specific volumes
S = Specific entropy
P = Pressure
T = Temperature
Manwell's equations are a set of equations derived by the application of Euler's relations to thermodynamic properties functions, Maxwell's relations are given are:

$$du = Tds - PdV \Rightarrow \left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

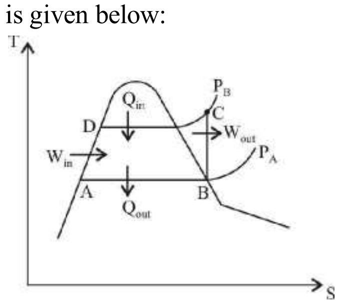
$$dA = -SdT - PdV \Rightarrow \left(\frac{\partial S}{\partial v}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

$$dH = TdS + VdP \Rightarrow \left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

$$dG = -SdT + VdP \Rightarrow \left(-\frac{\partial S}{\partial P}\right)_T = \left(\frac{\partial V}{\partial T}\right)_P$$

Where, U = Internal energy
A = Helmotz free energy
H = enthalpy
G = Gibbs free energy

13. (c) In care of a simple ideal Rankins cycle, when the turbine inlet temperature is increased, the thermal efficiency is increased and moisture content of steam is reduced at the turbine outlet. The T-S diagram for an ideal Rankins cycle is given below:



Process: A → B: Isentropic compression in a pump
Process: B–C: Heat added at constant pressure in a boiler
Process C–D: Isentropic expansion in a turbine
Process D–A: Heat rejected at constant pressure in a condenser.

14. (c) Hardenability of steel is a measure of the depth to which required hardening is obtained when it is austenitized and then quenched. It represents how deep the steel may be hardened upon quenching from high value temperature.

15. (d) The fluidity of molten metal of cast alloys (without any addition of fluxes) increases with increase in degree of super heat. Degree of super heat is defined or the amount by which the temperature of a superheated vapour exceeds the temperature of the saturated vapour at the same pressure.

16. (c) The cold forming process in which a hardened tool is pressed against a workpiece (when there is relative motion between the tool and the workpiece) to produce a roughened surface with a regular pattern is knurling. Knurling is done on the lathe machine, Cylindrical parts such as screw heads, round nuts, measurement tools, all types of handles etc.

17. (c) The most common limit gage used for inspecting the hole diameter is known as plug gage. These are usually assembled from standard parts, where the gage portion is interchangeable with other gage parts.

18. (c)

19. (3) Given data : 3, x, 2, 4

then, Mean $(x) = \dfrac{3+x+2+4}{4}$

$4x = 9 + x$

$4x - x = 9$

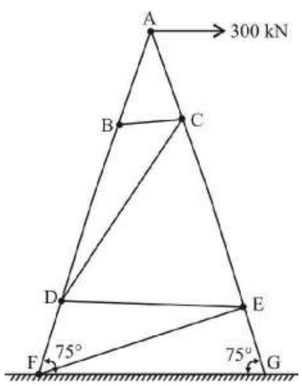
$3x = 9$

$x = \dfrac{9}{3} = 3$

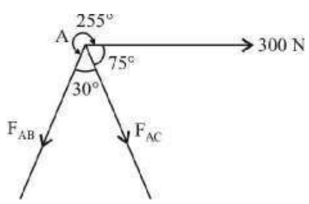
Now, the data values are : 3, 3, 2, 4

then, Mode = 3

20. (0) 'ON' Given data : Refer to figure showing an idealized truss,



considering a joint 'A'



Let, F_{AB} and F_{AC} = tensile forces in members AB and AC respectively.

Applying Lami's theorem,

$$\frac{F_{AB}}{\sin 75^\circ} = \frac{F_{AC}}{\sin 255^\circ} = \frac{300}{\sin 30^\circ}$$

$$F_{AB} = \frac{300}{\sin 30^\circ} \times \sin 75^\circ = 579.6 \text{ N (Tensile)}$$

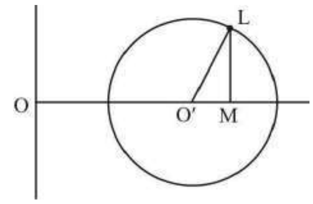
$$F_{AC} = \frac{300}{\sin 30^\circ} \times \sin 225 = -579.6\text{N (Compressive)}$$

As the members AB and BD are connected collinearly, hence $F_{BC} = 0$, Similarly members AC and CE are collinearly connected, hence $F_{CD} = 0$.

21. (80) MPa, Given data: Mohr's circle radius, R = 100 MPa

Normal stress, $\sigma_n = 260$ MPa

Refer to Figure showing Mohr's stress circle,



Let, τ = shear stress on the same plane at same point.

$OO' = 200$, $O'L = 100$, $OM = 260$;

From the geometry,

$(O'L)^2 = (O'M)^2 + (LM)^2$

or, $(O'L)^2 = (OM - OO')^2 + (LM)^2$

$(100)^2 = (260 - 200)^2 + (LM)^2$

$(100)^2 = (60)^2 + (LM)^2$

$(LM)^2 = 10000 - 3600$

$(LM)^2 = 6400$

$LM = \sqrt{6400} = 80\text{MPa}$

$\therefore \tau = 80\,\text{MP}a$

22. (50) MPa

Given data: diameter of wire, d = 1 mm

after bending of wire, radius of circular are,

R = 1 m

Young's modulur (E) = 100 GPa

Considering the Bending Equation,

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

where, M = bending Moment

I = Moment of inertia

σ = maximum tensile stress

y = distance of extreme fibre from matral axis

$y = \dfrac{d}{2} = \dfrac{1}{2} = 0.5$ mm

Now, $\dfrac{\sigma}{0.5} = \dfrac{100 \times 10^9}{1 \times 10^3}$

$\sigma = \dfrac{100 \times 10^9}{10^3} \times 0.5 = 5 \times 10^7$ Pa

$\sigma \approx 50$ MPa

23. (500)

Given data:

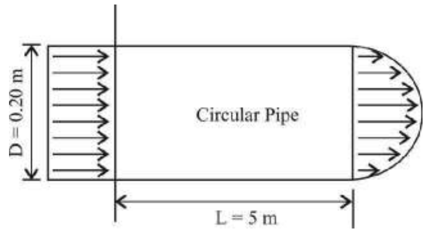
Length of pipe; L = 5 m

diameter of pipe, D = 0.20 m

Reynold's number, R_e = 500

At inlet of pipe, velocity of profile ⇒ uniform

At outlet of pipe, velocity of profile ⇒ parabolic



Reynold's number is given as:

$$R_e = \frac{PVD}{\mu}$$

$R_e \ \alpha \ D$

As pipe diameter is uniform the velocity is same for same discharge. Hence R_e will also be the same

24. (2) Given data:

height of plate = L_1 = L (for plate 1)

Nu $= KR_a^{1/4}$

Where, Nu = Nusselt number = $\frac{hL}{K}$

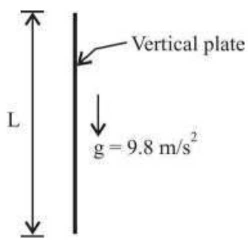
R_a = Rayleigh number

K = a (constant)

h_1 = average heat transfer coefficient of first plate

h_2 = average heat transfer coefficient of second plate

Refer to Fig.



height of plate = L_2 = 16L (for plate 2)

we know that, $R_a = Gr \times P_r$

where, G_r = Grashoff's number

Pr = Prandtl number

Nu α $(Gr)^{1/4}$

$$\frac{hL}{K} \alpha \left(\frac{g\beta dT \cdot L^3}{V^2}\right)^{1/4}$$

$hL \ \alpha \ (L^3)^{1/4} \Rightarrow hL \ \alpha \ L^{3/4}$

$$h \ \alpha \ \frac{L^{3/4}}{L} \Rightarrow h \ \alpha \ L^{3/4-1}$$

$$h \ \alpha \ L^{\frac{3-4}{4}} \Rightarrow h \ \alpha L^{-1/4}$$

$$\text{Now, } \frac{h_1}{h_2} = \frac{L_1^{-1/4}}{L_2^{-1/4}} \Rightarrow \frac{h_1}{h_2} = \frac{L_2^{1/4}}{L_1^{1/4}}$$

$$\frac{h_1}{h_2} = \left(\frac{L_2}{L_1}\right)^{1/4} = \left(\frac{16L}{L}\right)^{1/4}$$

$$\frac{h_1}{h_2} = (16)^{1/4} = 2$$

25. (1) J

Given data:

In EDM process,

break down voltage, V_B = 200V

capacitance of R_C circuit, C_{RC} = 50μF

$= 50 \times 10^{-6}$ F

Energy released per spark across IEG

$$= \frac{1}{2} \times C_{RC} \times V_B^2 = \frac{1}{2} \times 50 \times 10^{-6} \times (200)^2 = 1J$$

26. (c) 27. (a) 28. (b)

29. (d) Given data: Mass of ball $(m_A) = 3$ kg

Velocity, $u_A = 4$ m/s

$m_B = m$ = man of Stationary ball, and $u_B = 0$

After impact, kinetic energy, $(K.E)_A = 6J$

coefficient of restitution, $e = 1$

Considering conservation of momentum,

$m_A u_A + m_B u_B = m_A v_A + m_B v_B$

$(3 \times 4) + (m_B \times 0) = (3 \times v_A) + mv_B$

$12 + 0 = 3v_A + mv_B$

$3v_A + mv_B = 12$ ...(i)

Now, using the following relation,

$$e = \frac{v_B - v_A}{u_A - u_B}$$

$$I = \frac{v_B - v_A}{4 - 0}$$

$v_B - v_A = 4$ ...(ii)

Substituting the value of v_A from eqn. (ii) into eqn. (i) we get,

$3(v_B - 4) + mv_B = 12$

$3v_B - 12 + mv_B = 12$

$v_B(m + 3) = 12 + 12 = 24$

$$v_B = \frac{24}{m+3} \quad ...(iii)$$

Now, considering conservation of energy,

Initial kinetic energier = Final kinetic energier

$$\frac{1}{2} \times m_A \times u_A^2 + \frac{1}{2} \times m_A \times (0) = 6 + \frac{1}{2} mv_B^2$$

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

$$24 = 6 + \frac{1}{2} mv_B^2$$

$$\frac{1}{2} mv_B^2 = 24 - 6 = 18$$

$mv_B^2 = 18 \times 2 = 36$ ...(iv)

Substituting the value of v_B from eqn. (iii) into eqn. (iv) we get,

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

$$\frac{m \times 576}{(m+3)^2} = 36$$

$$(m^2 + 9 + 6m) = \frac{m \times 576}{36} = 16m$$

$m^2 + 6m - 16m + 9 = 0$

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

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

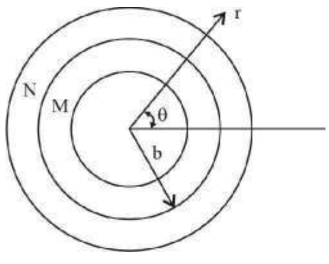
$m(m-1) - 9(m-1) = 0$

$(m-9)(m-1) = 0$

$m = 1$ kg, 9 kg

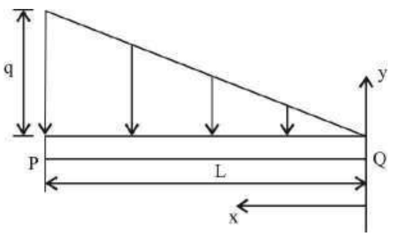
30. (a) Given data :

Interface at $r = b$ is frictionless. At the above location in radial direction, the radial displacement remained same.



$\therefore\ u_T^M = u_T^N$ and $\sigma_{rr}^M = \sigma_{rr}^N$

31. (b) Given data: Refer to figure given below:



Let us consider a section $(x-x)$ at a distance x from the free end 'B' of the beam,

Moment about $(x-x)$,

$$M_x = -\left(\frac{1}{2}\times x\times\frac{q_x}{L}\right)\times\frac{x}{3}$$

$$M_x = \frac{-qx^3}{6L}$$

As we know that,

$$M_x = E\frac{Id^3y}{dx^2} = -\frac{qx^3}{6L} \quad ...(i)$$

Integrating the eqn. (i), we have

$$\theta_x = \frac{E1dy}{dx} = \frac{-qx^4}{6\times 4L}+A_1 \quad ...(ii)$$

Again integrating, we get,

$$y_x = EI.y = \frac{-qx^5}{6\times 4\times 5L}+A_1x+A_2 \quad ...(iii)$$

Now, at fixed end, $x = L$, $\theta_P = 0$, $y_P = 0$, we get

$$\text{Slope } (\theta_P) = \frac{-qL^4}{24L}+A_1 = 0$$

$$A_1 = \frac{+qL^3}{24} \quad ..(iv)$$

$$\text{deflection } (y_P) = \frac{-qL^5}{120L}+\frac{qL^3}{24}(L)+A_2 = 0$$

$$A_2 = \frac{qL^4}{120}-\frac{qL^4}{24}$$

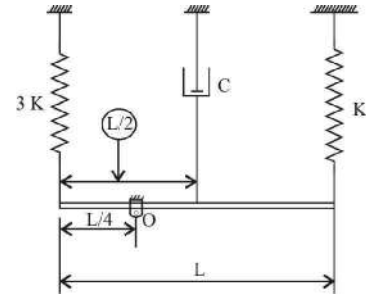
$$= \frac{qL^4-5qL^4}{120} = \frac{-4qL^4}{120}$$

$$A_2 = \frac{-qL^4}{30}$$

Magnitude of maximum deflection

$$y_{max.} = \frac{-qL^4}{30EI} \approx \frac{qL^4}{30EI}$$

32. (d) Given data : Refer to figures given below:



mass of slinder bar = m

Stiffness; $K_1 = K$, $K_2 = 3K$

damping coefficient = C

Let, moment of Inertia about 'O' = I_0

$$\text{Moment of Inertia about 'C'} = I_C = \frac{mL^2}{12}$$

$$R = \text{Radius} = \frac{L}{4}$$

then, $I_0 = I_C + mR^2$

$$\therefore\ I_0 = \frac{mL^2}{12}+m\left(\frac{L}{4}\right)^2$$

$$= \frac{mL^2}{12}+\frac{mL^2}{16} = \frac{4mL^2+3mL^2}{48}$$

$$I_0 = \frac{7mL^2}{48}$$

Now, take moments of all about the pivot point '0', we get,

$$I_0\ddot{\theta}+K_1\left(L-\frac{L}{4}\right)\times\theta\times\left(L-\frac{L}{4}\right)+K_2\left(\frac{L}{4}\right)\times\theta\times\frac{L}{4}$$

$$+C\left(\frac{L}{2}-\frac{L}{4}\right)\times\dot{\theta}\times\left(\frac{L}{2}-\frac{L}{4}\right) = 0$$

$$\text{or, } \frac{7mL^2}{48}\ddot{\theta}+K\times\frac{3L}{4}\times\ddot{\theta}\times\frac{3L}{4}+3K\times\frac{L}{4}\times\theta\times\frac{L}{4}+$$

$$C\times\frac{L}{4}\times\dot{\theta}\times\frac{L}{4} = 0$$

$$\text{or, } \frac{7mL^2}{48}\ddot{\theta}+\frac{9}{16}KL^2\theta+\frac{3}{16}KL^2\theta+\frac{C\dot{\theta}L^2}{16} = 0$$

$$\text{or, } \frac{7mL^2}{48}\ddot{\theta}+\frac{12}{16}KL^2\dot{\theta}+\frac{C\theta L^2}{16} = 0$$

or, rearranging equation,

$$\frac{7mL^2}{48}\ddot{\theta}\partial+\frac{C\dot{\theta}L^2}{16}+\frac{12KL^2}{16}\theta = 0$$

$$\frac{7m}{48}\ddot{\theta}+\frac{C\dot{\theta}}{16}+\frac{12K}{16}\theta = 0 \quad ...(i)$$

Equation (i) is equivalent to quadratic equation,

$$ax^2+bx+C = 0 \quad ..(ii)$$

$$\therefore\ a = \frac{7m}{48},\ b = \frac{c}{16},\ c = \frac{12K}{16}$$

$$b^2 = 4ac = 0$$

$$\left(\frac{C}{16}\right)^2-4\left(\frac{7m}{48}\right)\left(\frac{12k}{16}\right) = 0$$

$$\frac{C^2}{16\times16}=\frac{4\times7\,m}{3\times16}\times\frac{12K}{16}$$

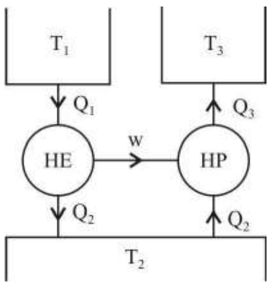
$C^2 = 112\,mk$

$C = \sqrt{112\,mK}$

$C = 4\sqrt{7}\times\sqrt{mK}$

$$\frac{C}{\sqrt{mK}} = 4\sqrt{7}$$

33. (c) Refer to figure given below:



Given data: $T_1 > T_3 > T_2$

CoP_{HP} = Coefficient of performance of heat pump

η_{He} = efficiency of heat engine

$$(CoP)_{HP} = \frac{Q_3}{w}$$

where, $Q_3 = Q_2 + w$ and, $w = Q_1 - Q_2 = Q_3 - Q_2$ ...(i)

$$\therefore\ (CoP)_{HP} = \frac{Q_2 + w}{w}$$

$$\eta_{H.E} = \frac{w}{Q_1} \text{ or } 1-\frac{Q_2}{Q_1} \Rightarrow \frac{Q_2}{Q_1} = 1-\eta_{H.E} \quad ..(ii)$$

$$\text{Now, } (CoP)_{H.P} = \frac{\text{Refrigeration effect}}{w} = \frac{Q_3}{Q_1 - Q_2}$$

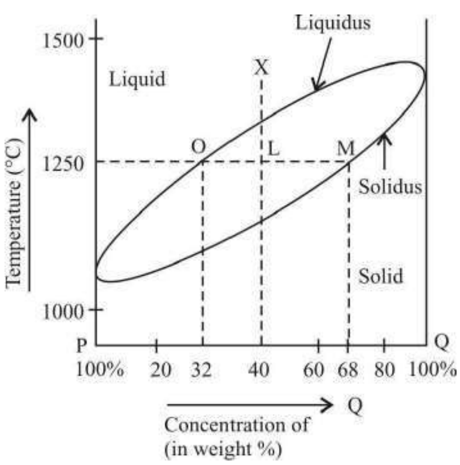
$$= \frac{\frac{Q_3}{Q_1}}{1-\frac{Q_2}{Q_3}} = \frac{1}{\eta_{H\cdot E}}$$

$\therefore\ (CoP)_{HP} = \eta_{H\cdot E}^{-1}$

or $CoP = \eta^{-1}$

34. (b) Refer to figure given below:

Let us consider liver rule for binary phase diagram given. The liver line is represented by OLM.



From the figure,

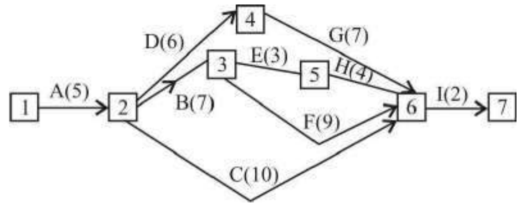
$$\%\ \text{Solid} = \frac{OL}{OM}\times100 = \frac{40-32}{68-32}\times100$$

$$= \frac{8}{36}\times100 = 22.22\%$$

$\%\ \text{liquid} = 100\% - 22.22\%$

$= 77.78\% \approx 77.8\%$

35. (c)



Path $A \to D \to G \to I = 5+6+7+2 = 20$ weeks

Path $A \to B \to E \to H \to I = 5+7+3+4+2 = 21$ weeks

Path $A \to B \to F \to I = 5+7+9+2 = 23$ weeks

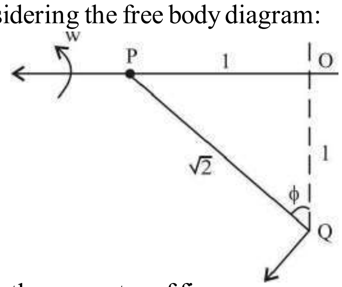
Path $A \to C \to I = 5+10+2 = 17$ weeks

Hence, time to complete the activities along the critical path is 23 weeks.

36. (c) Given data: w = constant angular velocity

r = length of crank

Considering the free body diagram:



From the geometry of figure:

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

$$\phi = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45^\circ$$

Let, a_p = acceleration of point 'P'

a_Q = acceleration of point 'Q'

a_{PQ} = acceleration of link 'PQ'

$\therefore\ a_Q = a_P + a_{PQ}$

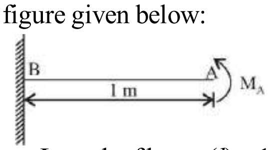
$a_Q = -\alpha\,.\,r\sin45^\circ - \alpha\,.\,r\,.\cos45^\circ$

or $\alpha + w^2r = 0 \Rightarrow \alpha = -w^2r$

then, $a_Q = -\alpha = -(-w^2r) = w^2r$

37. (2.5) mm

Refer to figure given below:



Given data: Length of beam (l) = 1 m

flexural rigidity (EI) = 200 N.m^2

applied moment (M_A) = 1 N.M

Let, y = magnitude of vertical deflection of free end

$$y = \frac{Ml^2}{2EI} = \frac{1\times1^2}{2\times200}$$

$y = 2.5\times10^{-3}$m

$y \approx 2.5$ mm

38. (41.23) kg

Given data: Refer to figure given below

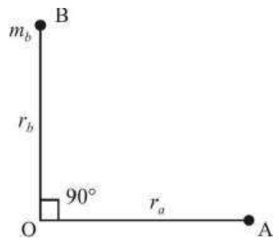
m_a = mass of ball A = 10 kg

m_b = mass of ball B = 20 kg

r_a = radius of rotation for ball 'A' = 200 mm

r_b = radius of rotation for ball 'B' = 400 mm

Let, $m_{bal.}$ = balanced mass of 'r_a'



Now, $(m_{bal.} r) = \sqrt{(m_a r_a)^2 + (m_a r_b)^2}$

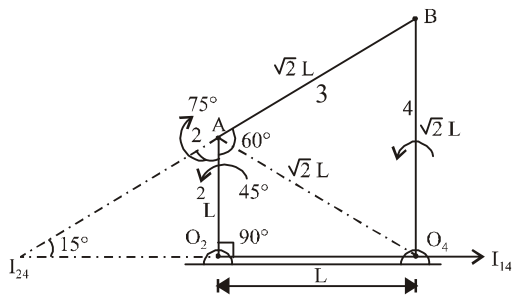
$= \sqrt{(10 \times 0.2)^2 + (20 \times 0.4)^2}$

$m_{bal.} r = \sqrt{(2)^2 + (8)^2} = \sqrt{4 + 64}$

$m_{bal.}\, r = 8.246$

$m_{bal.} = \dfrac{8.246}{0.2} = 41.23$ kg

39. (0.79) Refer to figure given below:



From the geometry of figures,

$\dfrac{\omega_4}{\omega_2} = \dfrac{I_{12} I_{24}}{I_{14} I_{24}}$ ...(i)

Considering $\Delta\, O_2AI_{24}$, we have

$I_{12}I_{24} = L \times \dfrac{\sin 75^\circ}{\sin 15^\circ} = L \times \dfrac{0.966}{0.259} = 3.72 \times 10^{-3} L$

$I_{14}I_{24} = 3.72 \times 10^{-3}L + 1 \times 10^{-3}L$

$= 4.72 \times 10^{-3}L$

Now, substituting the values $I_{12}I_{24}$ and $I_{14}I_{24}$ in Enq. (i)

$\dfrac{\omega_4}{\omega_2} = \dfrac{3.72 \times 10^{-3} L}{4.72 \times 10^{-3} L} = 0.79$

40. (0.17)

Probability of defective parts $P_d = P = 0.05$

Probability of non defective parts, $P'_{nd} = q = 1 - 0.05 = 0.95$

Number of parts selected randomly, n = 15

Now, probability that at least two parts will be defective,

$P(X \geq 2) = 1 - P(X < 2)$ ($\because$ x is number of defective parts)

$= 1 - \{P(X = 0) + P(X = 1)\}$ using Binomial distribution.

$= 1 - \left\{ {}^{15}C_0 P^0 q^n + {}^{15}C_1 P' q^{14} \right)$

$= 1 - \left\{ (0.95)^{15} + 15(0.05)(0.95)^{14} \right\}$

$= 1 - \{0.4633 + 0.3658\} = 1 - 0.8291$

$= 0.1709 \approx 0.17$

41. (–3) Given data : Radius of uniform disc = r

mass of disc = m

Length of axle, $l = 1.5\, r$

angular speed = ω

angular velocity, $w_p = \dfrac{w}{10}$

Resultant reaction forces= R_p and R_Q

$\omega^2 r = 300$ m/s², $g = 10$ m/s²

using the following relation,

$C = I\omega\omega_p$

where, C = Gyroscopic couple

I = moment of inertia = $\dfrac{mr^2}{2}$

$C = \dfrac{mr^2}{2} \times \dfrac{\omega \cdot \omega}{10}$

$C = \dfrac{mr^2\omega^2}{20}$

$= \dfrac{mr \cdot r\omega^2}{20} = \dfrac{m \cdot r \times 300}{20} = 15\, mr$

Reactions due to weight (*w*)

$R_P + R_Q = W = mg$

$R_P = R_Q$

then, $R_P = R_Q = \dfrac{mg}{2} = 5m$

Reactions due to gyroscopic couple

$R_P = -10m$, $R_Q = \dfrac{15\, mr}{L} = \dfrac{15\, mr}{1.5r} = 10\, m$

Now, Total reaction acting on the axle,

$(R_P) = -10m + 5m = -5m$

$(R_Q)_T = 5m + 10m = 15\, m$

Ratio of $\dfrac{(R_Q)_T}{(R_P)_T} = \dfrac{15\ m}{-5\ m} = -3$

42. (20.35) N

Given data :

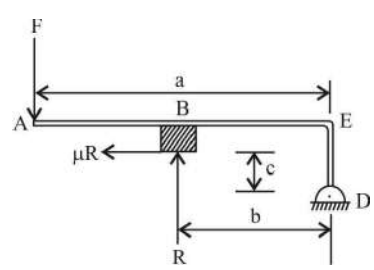
diameter of brake drum, $d = 500$ mm

dimension, $a = 1000$ mm, $b = 500$ mm, $c = 200$ mm

Coefficient of friction, $\mu = 0.35$

Force applied on lever, F = 100N

Refer to figure given below:



Taking moments about point 'D', $\Sigma M_D = 0$

$F \times AE + \mu R \times C = R \times b$

$F \times a + \mu R \times C = R \times b$

$100 \times 1000 + 0.35 \times R \times 200 = R \times 500$

$1000 + 0.35 \times 2 \times R = 5R$

$1000 + 0.7R = 5R$

$5R - 0.7R = 1000$

$4.3R = 1000$

$$R = \frac{1000}{4.3} = 232.56\,N$$

Braking torque acting the drum

$T_b = \mu . R \times r$

$$= 0.35 \times 232.56 \times \frac{500}{2} \times 10^{-3} = 20.35 N$$

43. (0.50)

Given data :

Length of pipe 'A', $L_A = 1$ m

Length of pipe 'B', $L_B = 2$ m

Cross-sectioned diameter, $D_A = D_B$

Head Losses, $(H_f)_A = (H_f)_B$

In case of a laminar flow,

$$\text{Frictional head loss, } H_f = \frac{32vvL}{PgD^2}$$

$$\text{Now, } \frac{32vv_A L_A}{PgD_A^2} = \frac{32vv_B L_B}{PgD_B^2}$$

or, $V_A L_A = V_B L_B$

$V_A \times 1 = V_B \times 2$

$$\frac{V_A}{V_B} = 2 \text{ or } \frac{V_B}{V_A} = \frac{1}{2} = 0.5$$

Now, Flow rate through pipe (A), $Q_A = A_A \times V_A$

$$= \frac{\pi}{4} D_A^2 \times V_A$$

Flow rate through pipe (B), $Q_B = A_B \times V_B$

$$= \frac{\pi}{4} D_B^2 \times V_B$$

$$\therefore \quad \frac{Q_B}{Q_A} = \frac{\frac{\pi}{4} D_B^2 \times V_B}{\frac{\pi}{4} D_A^2 \times V_A} = \frac{V_B}{V_A} = 0.50$$

44. (22) Km./hr.

Given, data :

Drag coefficient of car, $(C_d)_{car_1} = 0.1$ (windows and roof close)

Drag coefficient of car $(C_d)_{car_2} = 0.8$ (windows and roof open)

Speed of car (when windows and roof closed), $V_1 = 44$ km/hr.

Let, V_2 = speed of car (when windows and roof open)

Considering the following for equalization of power needed to overcomes the aerodynamic drag with roof and doors opened and closed.

$$F_{D_1} \times V_1 = F_{D_2} \times V_2$$

$$\frac{1}{2} \times (C_D)_{car_1} \times V_1^2 \times V_1 \times e_A$$

$$= \frac{1}{2} \times (C_D)_{car_2} \times V_2^2 \times V_2 \times e_A$$

$$\Rightarrow \frac{1}{2} \times 0.1 \times (44)^2 \times 44 = \frac{1}{2} \times (0.8) \times V_2^3.$$

$$0.1 \times (44)3 = (0.8) \times (0.8) \times V_2^3$$

$$V_2^3 = \frac{0.1 \times (44)^3}{0.8} = 10648$$

$$V_2 = \sqrt[3]{10648}$$

$$V_2 = 22 \text{ km/hr.}$$

45. (0.6)

Given data :

F_{IJ} = fraction of radiation leaving plate I that is intercepted by plate J

Similarly, $F_{LM} = 0.8$

$F_{NR} = 0.4$

$$F_{PQ} = \frac{F_{LM} + F_{NR}}{2} = \frac{0.8 + 0.4}{2} = \frac{0.12}{2} = 0.6$$

46. (57.76°)C

Given data :

For hot fluid, $t_{h_A} = 100°C$

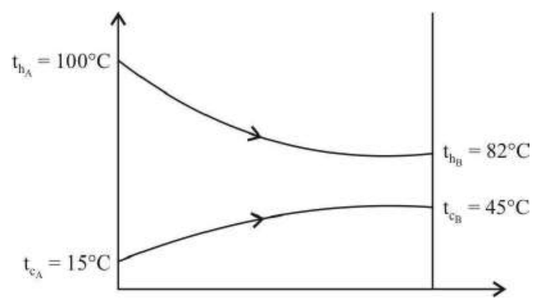
For cold fluid, $t_{C_A} = 15°C$, $t_{C_B} = 45°C$

heat capacity rate (for hot fluid), $C_H = 2000$ w/k

heat capacity rate (for cold fluid), $C_C = 1200$ w/k

Let, t_{h_B} = hot fluid temperature for 'B'

Refer to Figure given below:



For thermal equilibrium

Heat lost = heat achieved

$$C_h(t_{h_A} - t_{h_B}) = C_c(t_{c_B} - t_{c_A})$$

$$2000(100 - t_{h_B}) = 1200(45 - 15)$$

$$100 - t_{h_B} = \frac{1200 \times 30}{2000}$$

$$100 - t_{h_B} = 18$$

$$t_{h_B} = 100 - 18 = 82°C$$

Now, Logarithimic Mean Temperature Difference,

$$\text{LMTD} = \left[\frac{\theta_A - \theta_B}{\ln\left(\frac{\theta_A}{\theta_B}\right)}\right]$$

$$\text{when, } \theta_A = \left(t_{h_A} - t_{C_A}\right) = 100 - 15 = 85°C$$

$$\theta_B = \left(t_{h_B} - t_{C_B}\right) = 82 - 45 = 37°C$$

$$\text{LMTD} = \frac{85-37}{\ln\left(\frac{85}{37}\right)} = \frac{48}{\ln(2.297)} = \frac{48}{0.831} = 57.76^\circ\text{C}$$

47. (2.1) kw

Given that,
Rate of water flow, Q = 1 kg/s
Increase in enthalpy, $h_2 - h_1 = 2.5$ kJ/kg
Increase in specific entropy, $S_2 - S_1 = 0.007$ kJ/Kg. K
Power input to electric heater, $w = 2.5$ kw
Ambient temperature, $(T_Q) = 300$ k
Irreversibility rate of system,

$$I_R = T_a \times (S_2 - S_1) \times Q$$
$$= 300 \times 0.007 \times 1 = 2.1 \text{ kw}$$

48. (8.10) kg/s,

Given data:
Blade outer radius, $r_0 = 50$ mm
Power consumerd, $P_C = 2$ kw
Speed, N = 3000 rpm
Velocity of whirl at outlet,

$$u_2 = V_{\omega_2} = \frac{\pi D_0 N}{60} = \frac{\pi \times 2 \times 50 \times 10^{-3} \times 3000}{60}$$
$$= 15.71 \text{ m/s}$$
$$P_C = \dot{m}(V_{\omega_2} u_2 - V_{\omega_1} u_1)$$

when, V_{w_1} = Velocity of whirl at inlet = 0
u_1 = inlet velocity
u_2 = outlet velocity
m = Rate of mass flow

$$2000 = \dot{m}(15.71 \times 15.71 - 0)$$
$$\dot{m} = \frac{2000}{(15.71)^2} = 8.104 \text{ kg/s}$$
$$\approx 8.10 \text{ kg/s}$$

49. (708.8) kJ/kg

Given data :
For an air standard otto cycle,
thermal efficiency, $\eta_{otto} = 0.5$
mean effective pressure, mep = 1000 KPa
specific heat ratio, $\nu = 1.4$
Specific gas constant, R = 0.287 kJ/kg. K
At the beginning of compression stroke,
Pressure, $P_1 = 100$ KPa
temperature, $T_1 = 300$ K
using the following relation,

$$\eta_{otto} = 1 - \frac{1}{(r)^{\nu-1}}$$

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

$$0.5 = 1 - \frac{1}{(r)^{0.4}}$$

$$\frac{1}{(r)^{0.4}} = 1 - 0.5 = 0.5$$

$$(r)^{0.4} = \frac{1}{0.5} = 2$$

$$r = (2)^{\frac{1}{0.4}} = (2)^{2.50}$$

$r = 5.657$

Now, using the relation,

$$P_1V_1 = RT_1$$
$$100 \times V_1 = 0.287 \times 300$$
$$V_1 = \frac{0.287 \times 300}{100} = 0.861 \text{ m}^3/\text{kg}$$

Now, compression ratio, $r = \frac{V_1}{V_2}$

$$5.657 = \frac{0.861}{V_2}$$
$$V_2 = \frac{0.861}{5.657} = 0.1522 \text{ m}^3/\text{kg}$$

Now, if, W_N = Specific net work output of the cycle

$$mep = \frac{W_N}{V_1 - V_2}$$
$$1000 = \frac{W_N}{0.861 - 0.1522}$$
$$W_N = (0.861 - 0.1522) \times 1000$$
$$= 708.8 \text{ kJ/kg}$$

50. (28.9) Sec.

Given data:
Accleration due to gravity, $g = 9.81$ m/s^2
Size of mold cavity = 40 cm × 30 cm × 15 cm
Volume of mold cavity (V) = 40 × 30 × 15
= 18000 cm^3
Let, t = time to fill up the mold cavity
using the following relation,

$$\frac{V}{t} = A_1\sqrt{2gH_1}$$

when, A_1 = Area of cross-section of choks

$$= \frac{\pi}{4}(2)^2 = \pi \text{ cm}^2$$

H_1(Filling height) = 20 cm

$$\therefore \frac{18000}{t} = \pi\sqrt{2 \times 971 \times 20}$$

$$t = \frac{18000}{\pi\sqrt{2 \times 38120}} = \frac{18000 \times 7}{22 \times 198.09}$$

t = 28.9 seconds

51. (0.7) kJ/mm

Given data: In a GTAW operation,
Current, I = 250 A
Arc voltage, V = 20 V
weld speed, S = 5 mm/s
Arc efficiency, η_{arc} = 70% or 0.70
Heat input/unit length (H_{in})

$$= \frac{N_{\text{Duty cycle}} \times V \times I}{5} \times \eta_{arc}$$

$$= \frac{1 \times 20 \times 250}{5} \times 0.7$$

$$= 700 \text{ J/mm}$$
$$\approx 0.7 \text{ kJ/mm}$$

52. **(1.25)** mm

Diameter of rolls (D) = 600 mm
Coefficient of friction, (μ) = 0.05
initial sheet thickness, $t_i = 2$ mm
Let, t_f = final sheet thickness
Minimum possible final thickness; $(t_f) = t_i - (\Delta t)_{max.}$

Where, $(\Delta t)_{max.} = \dfrac{\mu^2 D}{2}$

$= \dfrac{(0.05)^2 \times 600}{2}$

$= 0.75$ mm

$\therefore \; t_f = 2 - 0.75$

$= 1.25$ mm

53. **(275) W**

Given data:
thickness of plate (t) = 15 mm
diameter of drill pit (D) = 10 mm
feed rate (f) = 0.25 mm/rev.
spindle speed (N) = 1200 rpm
Specific energy required, $(E_s) = 0.7$ Nm/mm^2
Let, P = Power requires for drilling
$\therefore$ $P = A \times f \times N \times E_S / 60$
Where, A = Area of cross-section

$= \dfrac{\pi}{4} D^2 = \dfrac{\pi}{4} \times (10)^2 = 25\pi \text{ mm}^2$

$\therefore \; P = \dfrac{25\pi \times 0.25 \times 1200 \times 0.7}{60}$

$= 275$ W

54. **(0.74)**

Given data:
Rake angle $(\alpha) = 10^\circ$
Uncut chip thickness, $t = 0.125$ mm
Chip thickness, $t_c = 0.22$ mm

Chip thickness ratio, $r_c = \dfrac{t_c}{t} = \dfrac{0.22}{0.125} = 1.76$

Now, using relation,

$\tan\phi = \dfrac{\cos\alpha}{r - \sin\alpha} = \left[\dfrac{\cos 10^\circ}{1.76 - \sin 10^\circ}\right]$

$\tan\phi = \left[\dfrac{0.9848}{1.76 - 0.1736}\right] = \left[\dfrac{0.9848}{1.5864}\right]$

$\tan\phi = 0.621$

$\phi = \tan^{-1}(0.621)$
$\phi = 31.8$
Condition for minimum cutting force,

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

or $\; 2\phi + \beta - \alpha = 90^\circ$
$2 \times 31.8 + \beta - 10^\circ = 90^\circ$
$\beta = 90 + 10 - 2 \times 31.8 = 90 + 10 - 63.6$
$\beta = 36.4^\circ$
Now, coefficient of friction of chip-tool interface,
$\mu = \tan\beta = \tan 36.4$
$\mu = 0.737$
$\mu \approx 0.74$

55. **(943.6)**

RS Given data :
Annual demand of valver/year, (D_a) = 10,000 units
Current order quantity, (Q) = 400 Valve$_h$/order
holding cost/valve/year, $(X_h) = 24$
Ordering cost/order, $(X_0) = 400$
Economic order Quantity,

$EOQ = \sqrt{\dfrac{2D_a X_0}{X_h}}$

$= \sqrt{\dfrac{2 \times 10,000 \times 400}{24}} = 577.35$

Inventory cost / year, $(IC)_1$

$= \sqrt{2D_a X_0 X_h}$

$= \sqrt{2 \times 10,000 \times 400 \times 24}$

= Rs. 13856.40

Inventory cost/year $(IC)_2$

$= \dfrac{D_a}{Q} \times X_0 + \dfrac{Q}{2} \times X_h$

$= \dfrac{10000}{400} \times 400 + \dfrac{400}{2} \times 24$

$= 10000 + 4800$

$(IC)_2$ = Rs. 14800

$\therefore$ Saving in the total cost of inventory per year

$= (IC)_2 - (IC)_1$
$= 14800 - 13856.40$
= Rs. 943.6

GATE MECHANICAL ENGINEERING SOLVED PAPER

2018 SET - 1

Duration: 3 hrs **Maximum Marks: 100**

INSTRUCTIONS

1. There are a total of 65 questions carrying 100 marks.
2. The subject specific GATE paper section consists of 55 questions. The GA section consists of 10 questions.
3. Questions are of Multiple Choice Question (MCQ) or Numerical Answer type. A multiple choice question will have four choices for the answer with only one correct choice. For numerical answer type questions, the answer is a number and no choices will be given.
4. Questions not attempted will result in zero mark. Wrong answers for multiple choice type questions will result in NEGATIVE marks. For all 1 mark questions, $\frac{1}{3}$ mark will be deducted for each wrong answer. For all 2 marks questions, $\frac{2}{3}$ mark will be deducted for each wrong answer.
5. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE.**

Question 1- 5 carry one mark each.

1. " Going by the _________ that many hands make light work, the school _______ involved all the students in the task."
The words that best fill the blanks in the above sentence are
(a) principle, principal (b) principal, principle
(c) principle, principle (d) principal, principal

2. " Her _______ should not be confused with miserliness; she is ever willing to assist those in need."
The word that best fills the blank in the above sentence is
(a) cleanliness (b) punctuality
(c) frugality (d) greatness

3. Seven machines take 7 minutes to make 7 identical toys. At the same rate, how many minutes would it take for 100 machines to make 100 toys?
(a) 1 (b) 7
(c) 100 (d) 700

4. A rectangle becomes a square when its length and breadth are reduced by 10 m and 5 m, respectively. During this process, the rectangle loses 650 m2 of area. What is the area of the original rectangle in square meters?
(a) 1125 (b) 2250
(c) 2924 (d) 4500

5. A number consists of two digits. The sum of the digits is 9. If 45 is subtracted from the number, its digits are interchanged. What is the number?
(a) 63 (b) 72
(c) 81 (d) 90

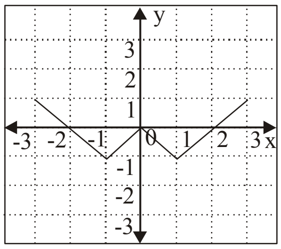
Questions 6-10 carry two marks each.

6. For integers a, b and c, what would be the minimum and maximum values respectively of $a + b + c$ if $\log |a| + \log |b| + \log |c| = 0$?
(a) –3 and 3 (b) –1 and 1
(c) –1 and 3 (d) 1 and 3

7. Given that a and b are integers and $a + a^2 b^3$ is odd, which one of the following statements is correct?
(a) a and b are both odd (b) a and b are both even
(c) a is even and b is odd (d) a is odd and b is even

8. From the time the front of a train enters a platform, it takes 25 seconds for the back of the train to leave the platform, while travelling at a constant speed of 54 km/h. At the same speed, it takes 14 seconds to pass a man running at 9 km/h in the same direction as the train. What is the length of the train and that of the platform in meters, respectively?
(a) 210 and 140 (b) 162.5 and 187.5
(c) 245 and 130 (d) 175 and 200

9. Which of the following functions describe the graph shown in the below figure?



(a) $y = ||x|+1|-2$ (b) $y = ||x|-1|-1$

(c) $y = ||x|+1|-1$ (d) $y = ||x-1|-1|$

10. Consider the following three statements:
(i) Some roses are red.
(ii) All red flowers fade quickly.
(iii) Some roses fade quickly.
Which of the following statements can be logically inferred from the above statements?
(a) If (i) is true and (ii) is false, then (iii) is false.
(b) If (i) is true and (ii) is false, then (iii) is true.
(c) If (i) and (ii) are true, then (iii) is true.
(d) If (i) and (ii) are false, then (iii) is false.

TECHNICAL

Questions 1-25 carry one mark each.

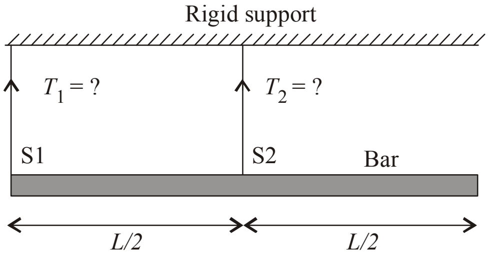
1. Four red balls, four green balls and four blue balls are put in a box. Three balls are pulled out of the box at random one after another without replacement. The probability that all the three balls are red is
(a) 1/72 (b) 1/55
(c) 1/36 (d) 1/27

2. The rank of the matrix $\begin{bmatrix} -4 & 1 & -1 \\ -1 & -1 & -1 \\ 7 & -3 & 1 \end{bmatrix}$ is
(a) 1 (b) 2
(c) 3 (d) 4

3. According to the Mean Value Theorem, for a continuous function $f(x)$ in the interval $[a, b]$, there exists a value ξ in this interval such that $\int_a^b f(x)dx$
(a) $f(\xi)(b-a)$ (b) $f(b)(\xi-a)$
(c) $f(a)(b-\xi)$ (d) 0

4. $F(z)$ is a function of the complex variable $z = x + iy$ given by $F(z) = i z = k\, Re(z) + i\, Im(z)$
For what value of k will $F(z)$ satisfy the Cauchy-Riemann equations?
(a) 0 (b) 1
(c) 1 (d) y

5. A bar of uniform cross section and weighing 100 N is held horizontally using two massless and inextensible strings S1 and S2 as shown in the figure.



The tensions in the strings are
(a) $T_1 = 100$ N and $T_2 = 0$ N (b) $T_1 = 0$ N and $T_2 = 100$ N
(c) $T_1 = 75$ N and $T_2 = 25$ N (d) $T_1 = 25$ N and $T_2 = 75$ N

6. If σ_1 and σ_3 are the algebraically largest and smallest principal stresses respectively, the value of the maximum shear stress is
(a) $\dfrac{\sigma_1+\sigma_3}{2}$ (b) $\dfrac{\sigma_1-\sigma_3}{2}$
(c) $\sqrt{\dfrac{\sigma_1+\sigma_3}{2}}$ (d) $\sqrt{\dfrac{\sigma_1-\sigma_3}{2}}$

7. The equation of motion for a spring-mass system excited by a harmonic force is $M\ddot{x} + Kx = F\cos(\omega t)$, where M is the mass, K is the spring stiffness, F is the force amplitude and ω is the angular frequency of excitation. Resonance occurs when ω is equal to
(a) $\sqrt{\dfrac{M}{K}}$ (b) $\dfrac{1}{2\pi}\sqrt{\dfrac{K}{M}}$
(c) $2\pi\sqrt{\dfrac{K}{M}}$ (d) $\sqrt{\dfrac{K}{M}}$

8. For an Oldham coupling used between two shafts, which among the following statements are correct?
I. Torsional load is transferred along shaft axis.
II. A velocity ratio of 1:2 between shafts is obtained without using gears.
III. Bending load is transferred transverse to shaft axis.
IV. Rotation is transferred along shaft axis.
(a) I and III (b) I and IV
(c) II and III (d) II and IV

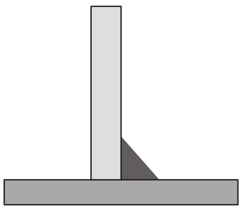
9. For a two-dimensional incompressible flow field given by $\vec{u} = A(x\hat{i} - y\hat{j})$, where $A > 0$, which one of the following statements is FALSE?
(a) It satisfies continuity equation.
(b) It is unidirectional when $x \to 0$ and $y \to \infty$.
(c) Its streamlines are given by $x = y$.
(d) It is irrotational.

10. Which one of the following statements is correct for a superheated vapour?
(a) Its pressure is less than the saturation pressure at a given temperature.
(b) Its temperature is less than the saturation temperature at a given pressure.

(c) Its volume is less than the volume of the saturated vapour at a given temperature.
(d) Its enthalpy is less than the enthalpy of the saturated vapour at a given pressure.

11. In a linearly hardening plastic material, the true stress beyond initial yielding
(a) increases linearly with the true strain
(b) decreases linearly with the true strain
(c) first increases linearly and then decreases linearly with the true strain
(d) remains constant

12. The type of weld represented by the shaded region in the figure is



(a) groove (b) spot
(c) fillet (d) plug

13. Using the Taylor's tool life equation with exponent $n = 0.5$, if the cutting speed is reduced by 50%, the ratio of new tool life to original tool life is
(a) 4 (b) 2
(c) 1 (d) 0.5

14. A grinding ratio of 200 implies that the
(a) grinding wheel wears 200 times the volume of the material removed
(b) grinding wheel wears 0.005 times the volume of the material removed
(c) aspect ratio of abrasive particles used in the grinding wheel is 200
(d) ratio of volume of abrasive particle to that of grinding wheel is 200

15. Interpolator in a CNC machine
(a) controls spindle speed
(b) coordinates axes movements
(c) operates tool changer
(d) commands canned cycle

16. The time series forecasting method that gives equal weightage to each of the m most recent observations is
(a) Moving average method
(b) Exponential smoothing with linear trend
(c) Triple Exponential smoothing
(d) Kalman Filter

17. The number of atoms per unit cell and the number of slip systems, respectively, for a facecentered cubic (FCC) crystal are
(a) 3, 3 (b) 3, 12
(c) 4, 12 (d) 4, 48

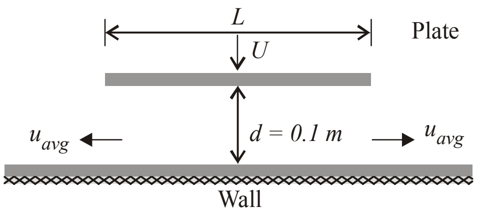
18. A six-faced fair dice is rolled five times. The probability (in %) of obtaining "ONE" at least four times is
(a) 33.3 (b) 3.33
(c) 0.33 (d) 0.0033

19. A steel column of rectangular section (15 mm × 10 mm) and length 1.5 m is simply supported at both ends. Assuming modulus of elasticity, E = 200 GPa for steel, the critical axial load (in kN) is ____ (correct to two decimal places).

20. A four bar mechanism is made up of links of length 100, 200, 300 and 350 mm. If the 350 mm link is fixed, the number of links that can rotate fully is __________.

21. I f the wire diameter of a compressive helical spring is increased by 2%, the change in spring stiffness (in %) is _____ (correct to two decimal places).

22. A flat plate of width $L = 1$ m is pushed down with a velocity $U = 0.01$ m/s towards a wall resulting in the drainage of the fluid between the plate and the wall as shown in the figure. Assume two-dimensional incompressible flow and that the plate remains parallel to the wall.
The average velocity, u_{avg} of the fluid (in m/s) draining out at the instant shown in the figure is _____________ (correct to three decimal places).



23. A n ideal gas undergoes a process from state 1(T_1 = 300 K, p_1 = 100 kPa) to state 2 (T_2 = 600 K, 2 p_2 = 500 kPa). The specific heats of the ideal gas are : c_p = 1 kJ/kg-K and c_v = 0.7 kJ/kg-K. The change in specific entropy of the ideal gas from state 1 to state 2 (in kJ/kg-K) is _________ (correct to two decimal places).

24. For a Pelton wheel with a given water jet velocity, the maximum output power from the Pelton wheel is obtained when the ratio of the bucket speed to the water jet speed is _______ (correct to two decimal places).

25. The height (in mm) for a 125 mm sine bar to measure a taper of 27°32' on a flat work piece is _______ (correct to three decimal places).

Quesions 26 – 55 carry two marks each.

26. Let X_1, X_2 be two independent normal random variables with means μ_1, μ_2 and standard deviations σ_1, σ_2, respectively. Consider $Y = X_1 - X_2$; $\mu_1 = \mu_2 = 1$, $\sigma_1 = 1$, $\sigma_2 = 2$. Then,
(a) Y is normally distributed with mean 0 and variance 1
(b) Y is normally distributed with mean 0 and variance 5
(c) Y has mean 0 and variance 5, but is NOT normally distributed
(d) Y has mean 0 and variance 1, but is NOT normally distributed

27. The value of the integral

$$\oiint_s \vec{r} \cdot \vec{n}\, dS$$

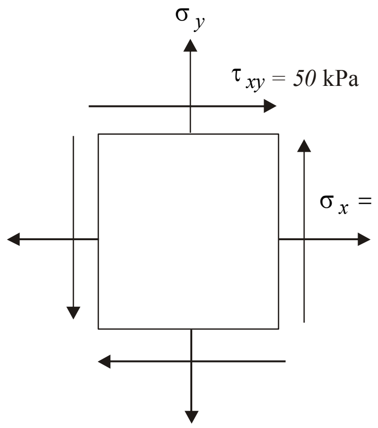
over the closed surface S bounding a volume V, where $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ is the position vector and n is the normal to the surface S, is

(a) V (b) $2V$
(c) $3V$ (d) $4V$

28. A point mass is shot vertically up from ground level with a velocity of 4 m/s at time, $t = 0$. It loses 20% of its impact velocity after each collision with the ground. Assuming that the acceleration due to gravity is 10 m/s^2 and that air resistance is negligible, the mass stops bouncing and comes to complete rest on the ground after a total time (in seconds) of

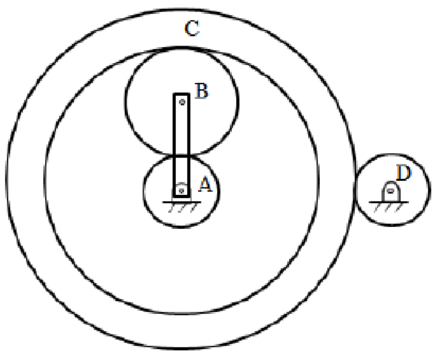
(a) 1 (b) 2
(c) 4 (d) ∞

29. The state of stress at a point, for a body in plane stress, is shown in the figure below. If the minimum principal stress is 10 kPa, then the normal stress σ_y (in kPa) is



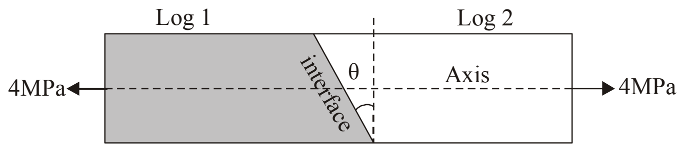
(a) 9.45 (b) 18.88
(c) 37.78 (d) 75.50

30. An epicyclic gear train is shown in the figure below. The number of teeth on the gears A, B and D are 20, 30 and 20, respectively. Gear C has 80 teeth on the inner surface and 100 teeth on the outer surface. If the carrier arm AB is fixed and the sun gear A rotates at 300 rpm in the clockwise direction, then the rpm of D in the clockwise direction is



(a) 240 (b) –240
(c) 375 (d) –375

31. A carpenter glues a pair of cylindrical wooden logs by bonding their end faces at an angle of $\theta = 30°$ as shown in the figure.



$\theta = 30°$

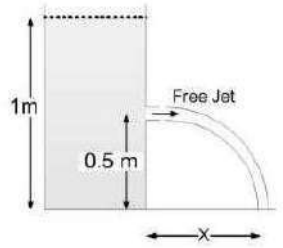
The glue used at the interface fails if
Criterion 1: the maximum normal stress exceeds 2.5 MPa.
Criterion 2: the maximum shear stress exceeds 1.5 MPa.
Assume that the interface fails before the logs fail. When a uniform tensile stress of 4 MPa is applied, the interface

(a) fails only because of criterion 1
(b) fails only because of criterion 2
(c) fails because of both criteria 1 and 2
(d) does not fail

32. A self-aligning ball bearing has a basic dynamic load rating (C_{10}, for 10^6 revolutions) of 35 kN. If the equivalent radial load on the bearing is 45 kN, the expected life (in 10^6 revolutions) is

(a) below 0.5 (b) 0.5 to 0.8
(c) 0.8 to 1.0 (d) above 1.0

33. A tank open at the top with a water level of 1 m, as shown in the figure, has a hole at a height of 0.5 m. A free jet leaves horizontally from the smooth hole. The distance X (in m) where the jet strikes the floor is



(a) 0.5 (b) 1.0
(c) 2.0 (d) 4.0

34. In a Lagrangian system, the position of a fluid particle in a flow is described as $x = x_o e^{-kt}$ and $y = y_o e^{kt}$ where t is the time while x_o, y_o and k are constants. The flow is

(a) unsteady and one-dimensional
(b) steady and two-dimensional
(c) steady and one-dimensional
(d) unsteady and two-dimensional

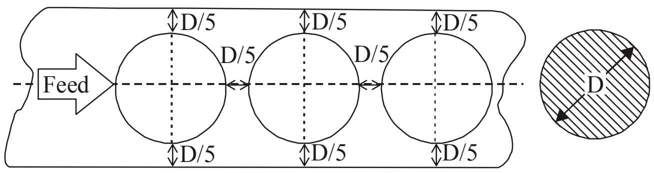
35. The maximum reduction in cross-sectional area per pass (R) of a cold wire drawing process is

$$R = 1 - e^{-(n+1)}$$

where n represents the strain hardening coefficient. For the case of a perfectly plastic material, R is

(a) 0.865 (b) 0.826
(c) 0.777 (d) 0.632

36. The percentage scrap in a sheet metal blanking operation of a continuous strip of sheet metal as shown in the figure is _______ (correct to two decimal places).



37. An explicit forward Euler method is used to numerically integrate the differential equation

$$\frac{dy}{dt} = y$$

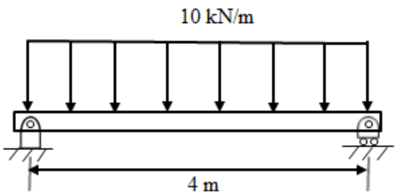
using a time step of 0.1. With the initial condition y(0) = 1, the value of $y(1)$ computed by this method is ___________ (correct to two decimal places).

38. $F(s)$ is the Laplace transform of the function

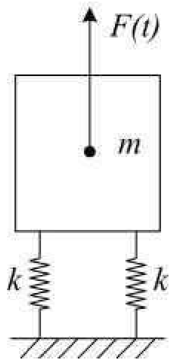
$f(t) = 2t^2e^{-t}$

$F(1)$ is ________ (correct to two decimal places).

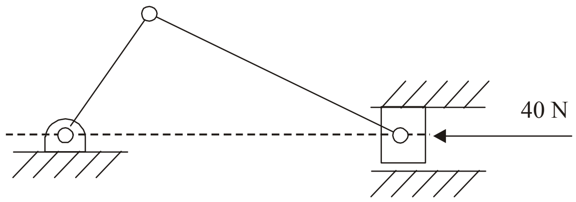
39. A simply supported beam of width 100 mm, height 200 mm and length 4 m is carrying a uniformly distributed load of intensity 10 kN/m. The maximum bending stress (in MPa) in the beam is __________ (correct to one decimal place).



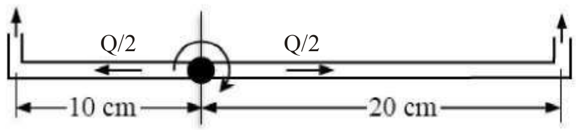
40. A machine of mass m = 200 kg is supported on two mounts, each of stiffness k = 10 kN/m. The machine is subjected to an external force (in N) $F(t)$ = 50 cos 5t. Assuming only vertical translatory motion, the magnitude of the dynamic force (in N) transmitted from each mount to the ground is ______ (correct to two decimal places).



41. A slider crank mechanism is shown in the figure. At some instant, the crank angle is 45° and a force of 40 N is acting towards the left on the slider. The length of the crank is 30 mm and the connecting rod is 70 mm. Ignoring the effect of gravity, friction and inertial forces, the magnitude of the crankshaft torque (in Nm) needed to keep the mechanism in equilibrium is _________ (correct to two decimal places).



42. A sprinkler shown in the figure rotates about its hinge point in a horizontal plane due to water flow discharged through its two exit nozzles.

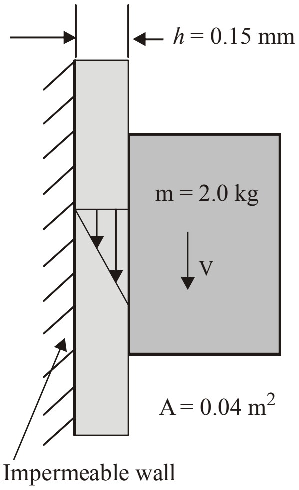


The total flow rate Q through the sprinkler is 1 litre/sec and the cross-sectional area of each exit nozzle is 1 cm^2. Assuming equal flow rate through both arms and a frictionless hinge, the steady state angular speed of rotation (in rad/s) of the sprinkler is ______ (correct to two decimal places).

43. A solid block of 2.0 kg mass slides steadily at a velocity V along a vertical wall as shown in the figure below. A thin oil film of thickness h = 0.15 mm provides lubrication between the block and the wall. The surface area of the face of the block in contact with the oil film is 0.04 m^2. The velocity distribution within the oil film gap is linear as shown in the figure.

Take dynamic viscosity of oil as 7×10^{-3} Pa-s and acceleration due to gravity as 10 m/s^2.

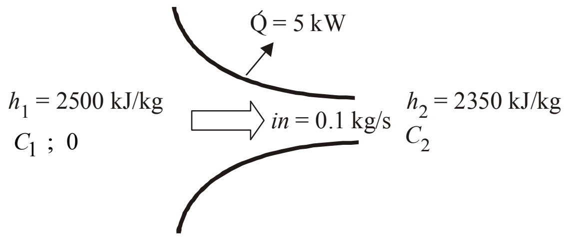
Neglect weight of the oil. The terminal velocity V (in m/s) of the block is _________ (correct to one decimal place).



44. A tank of volume 0.05 m^3 contains a mixture of saturated water and saturated steam at 200°C. The mass of the liquid present is 8 kg. The entropy (in kJ/kg K) of the mixture is ___________ (correct to two decimal places).

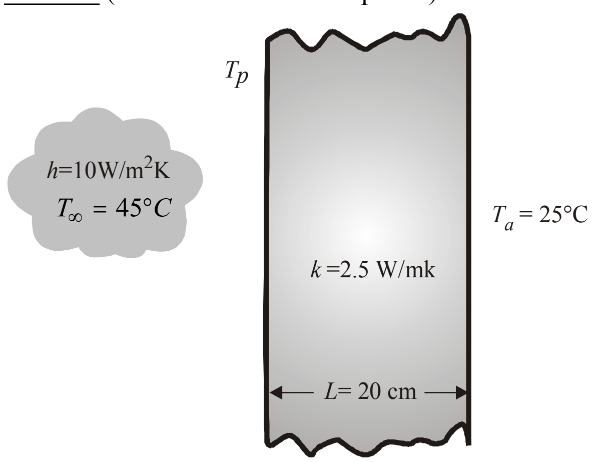
Property data for saturated steam and water are:
At 200°C, P_{sat} = 1.5538 MPa
v_f = 0.001157 m^3/kg, v_g = 0.12736 m^3/kg
s_{fg} = 4.1014 kJ/kg, K s_f =2.3309 kJ/kg K

45. Steam flows through a nozzle at a mass flow rate of m =0.1 kg/s with a heat loss of 5 kW. The enthalpies at inlet and exit are 2500 kJ/kg and 2350 kJ/kg, respectively. Assuming negligible velocity at inlet ($C_1 \approx 0$), the velocity (C_2) of steam (in m/s) at the nozzle exit is __________ (correct to two decimal places).

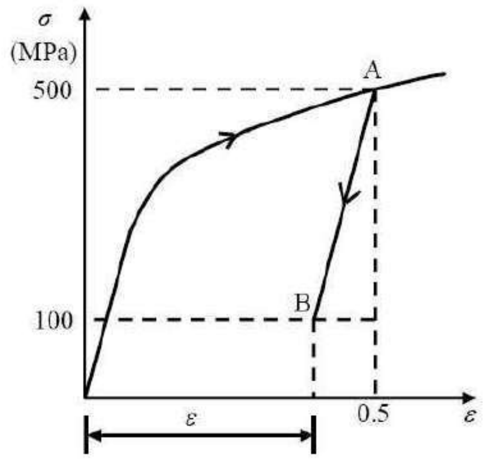


46. A n engine working on air standard Otto cycle is supplied with air at 0.1 MPa and 35°C. The compression ratio is 8. The heat supplied is 500 kJ/kg. Property data for air: c_p = 1.005 kJ/kg K, c_v = 0.718 kJ/kg K, R = 0.287 kJ/kg K. The maximum temperature (in K) of the cycle is _________ (correct to one decimal place).

47. A plane slab of thickness L and thermal conductivity k is heated with a fluid on one side (P), and the other side (Q) is maintained at a constant temperature, T_Q of 25°C, as shown in the figure. The fluid is at 45°C and the surface heat transfer coefficient, h, is 10 W/m^{2}K. The steady state temperature, T_P, (in °C) of the side which is exposed to the fluid is _______ (correct to two decimal places).



48. The true stress (σ) -true strain (ε) diagram of a strain hardening material is shown in figure. First, there is loading up to point A, i.e., up to stress of 500 MPa and strain of 0.5. Then from point A, there is unloading up to point B, i.e., to stress of 100 MPa. Given that the Young's modulus E = 200 GPa, the natural strain at point B (ε_B) is _________ (correct to three decimal places).



49. An orthogonal cutting operation is being carried out in which uncut thickness is 0.010 mm, cutting speed is 130 m/min, rake angle is 15° and width of cut is 6 mm. It is observed that the chip thickness is 0.015 mm, the cutting force is 60 N and the thrust force is 25 N. The ratio of friction energy to total energy is __________ (correct to two decimal places).

50. A bar is compressed to half of its original length. The magnitude of true strain produced in the deformed bar is _________________ (correct to two decimal places).

51. The minimum value of $3x + 5y$
such that:
$3x + 5y \le 15$
$4x + 9y \le 8$
$13x + 2y \le 2$
$x \ge 0, y \ge 0$
is _______.

52. Processing times (including setup times) and due dates for six jobs waiting to be processed at a work center are given in the table. The average tardiness (in days) using shortest processing time rule is ___________ (correct to two decimal places).

Job	Processing time (days)	Due date (days)
A	3	8
B	7	16
C	4	4
D	9	18
E	5	17
F	13	19

53. The schematic of an external drum rotating clockwise engaging with a short shoe is shown in the figure. The shoe is mounted at point Y on a rigid lever XYZ hinged at point X. A force F = 100 N is applied at the free end of the lever as shown. Given that the coefficient of friction between the shoe and the drum is 0.3, the braking torque (in Nm) applied on the drum is _______ (correct to two decimal places).