Mock Test 4

Number of Questions: 65 **Total Marks: 100**

Wrong answer for MCQ will result in negative marks, (-1/3) for 1 Mark Questions and (-2/3) for 2 Marks Question.

General Aptitude

Number of Questions: 10 **Section Marks: 15**

Questions 1 to 5 carry One Mark each.

Directions for question 1: Choose the most appropriate word from the options given below to complete the following sentence.

1. Despite its known toxicity, lead continues to be used, to the great _____ of human and environmental health.
(A) impediment (B) detriment
(C) chagrin (D) solace

Directions for questions 2 and 3: Select the correct alternative from the given choices.

2. A 7-year old child assembles an object from lego blocks. The object is in the shape of a cylinder surmounted by a hemisphere of radius 7 cm. If the height of the cylinder is 7 cm, find the volume of the object (in cm^3).
(A) $\frac{3\pi}{5}(7^2)$ (B) $\frac{5\pi}{3}(7^3)$
(C) 7^3 (D) $7^3\pi$

3. In a certain code language, if Zoology is called Anthropology, Anthropology is called Ornithology, Ornithology is called Biology, Biology is called Cosmology, Cosmology is called Ecology, Ecology is called Etymology, then what is the study of human called in that language?
(A) Biology (B) Ecology
(C) Ornithology (D) Cosmology

Directions for question 4: Select the pair that best expresses a relationship similar to that expressed in the capitalized pair.

4. BIOLOGY: LIFE
(A) Archaeology: Antiques
(B) Astrology: Stars
(C) Cosmetology: Beauty
(D) Mythology : Myths

Directions for question 5: Fill in the blanks from the options given below:

5. _____ summer monsoon _____ been showing a weakening trend _____ the past century with decreasing rainfall over large regions of _____ Indian subcontinent.
(A) The, has, over, the
(B) The, has, over, no article
(C) A, had, across, no article
(D) The, has, in, the

Questions 6 to 10 carry Two Marks each.

Directions for questions 6 to 10: Select the correct alternative from the given choices.

6. a, b, c, d are distinct positive integers such that:
$f(a, b, c, d) = \max(a, b, c, d)$
$g(a, b, c, d) = \min(a, b, c, d)$
$h(a, b, c, d)$ = remainder of $(c \times d / a \times b)$
If $(c \times d) > (a \times b)$
$h(a, b, c, d)$ = remainder of $(a \times b) / (c \times d)$ if $(c \times d) < (a \times b)$
Also, a function fgh $(a, b, c, d) = f(a, b, c, d) \times g(a, b, c, d) \times h(a, b, c, d)$
the value of $fg[h(12, 11, 8, 16), 17, 9, 16]$ _____

7. Textbooks of medicine say that there is no direct connection between the brain and the lymphatic system, yet a paper published in the journal *Nature* refers to the discovery of exactly such a connection.
Which one of the statements given below is logically valid and can be inferred from the above sentence.
(A) A paper published in the journal *Nature* corroborates the fact that there is no direct connection between the brain and the lymphatic system.
(B) Textbooks of medicine declare that there is no direct connection between the brain and the lymphatic system and this is affirmed by a paper published in the journal *Nature*.
(C) Texts of medicine proclaim that there is no direct connection between the brain and the lymphatic system but a paper published in the journal *Nature* says that such a connection is indeed there.
(D) While textbooks of medicine maintain that there is no direct connection between the brain and the lymphatic system, a paper published in the journal *Nature* claims that the brain and the lymphatic system are connected indirectly.

8. The last decade has witnessed a slow but steady realisation within the Indian government that the threats of the future will come from cyberspace. Unfortunately, while the realisation exists, the Indian security establishment has not been jolted into action in the manner in which the Kargil War or the 26/11 terrorist attack on Mumbai

galvanised the nation into adopting a series of corrective measures.

Which of the statement(s) below is/are logically valid and can be inferred from the above passage?

(i) Although the Indian government realizes that the threats of the future will be from cyberspace, it is yet to accord the seriousness which is due to this threat.

(ii) Despite the fact that the Indian government realizes that the future threats will come from cyberspace, it does not consider these threats as devious as other threats which spurred the government to adopt corrective measures.

(iii) The Indian government considers that the threats from cyberspace will not pose a serious threat to the security of the nation.

(iv) The Indian government fails to consider that the threats from cyberspace could pose a threat to the security of a nation.

(A) Only i (B) i and ii
(C) iii and iv (D) i, ii and iii

9. 30 students in class of BV School, wrote a test with 4 questions. For each question the number of students who answered correctly, incorrectly and did not attempt are tabulated below. The marks for each question are also listed in the table. There is no negative marking or partial marking.

Q.No.	Marks	Answered correctly	Answered incorrectly	Did not attempt
1	3	15	5	10
2	2	10	7	13
3	2	20	9	1
4	1	11	10	9

If the number of students who attempted all questions is 5, what is the maximum possible number of students who left at least 2 questions unattempted?

(A) 3 (B) 16
(C) 8 (D) None of these

10. The given statement is followed by some courses of action. Assuming the statement to be true, decide which of the given courses of action logically follows for pursuing.

Statement:

There have been steep increases in the government's expenditures on garbage collection, sorting, storage and recycling.

Courses of action:

(i) Government should encourage people to sort their garbage, by providing them separate bins for dry and wet garbage.

(ii) Once garbage is collected from households, to the extent possible it should be directed towards recycling, so that it can cut down on storage costs.

(iii) The routes of the collection vehicles should be planned in such a way that they are used in a most efficient manner.

(A) Only (i) and (ii) follow
(B) Only (ii) and (iii) follow
(C) Only (i) and (iii) follow
(D) All (i), (ii) and (iii) follow

MECHANICAL ENGINEERING

Directions for questions 1 to 55: Select the correct alternative from the given choices.

Questions 1 to 25 carry One Mark each.

11. Which of the following statements is NOT true for every real skew-symmetric matrix A?

(A) The product of all the eigen values of A is zero.
(B) The eigen values of A are either zero or purely imaginary.
(C) Every principal diagonal element of A is zero.
(D) Sum of all the elements of A is zero.

12. The value of $\lim_{x\to 3} \log_5\left[4x^3 + \sqrt{(3x^4 + 5x^2 + 1)}\right]$ is _____

13. The absolute error in the process of finding the real root of $x^3 + x^2 + 4x + 4 = 0$ by Newton-Raphson method with initial approximation $x_o = 2$ after one iteration is _____.

14. If 'a' is a positive real number, then which of the following periodic functions with period '$2a$' will have only sine terms in its Fourier series expansion?

(A) $f(x) = a + x \begin{cases} a+x & -a \le x < 0 \\ a-x & 0 \le x \le a \end{cases}$
(B) $f(x) = |x|; -a \le x \le a$
(C) $f(x) = 3x^2 + 5; -a \le x \le a$
(D) $f(x) = x^3 - 2x; -a \le x \le a$

15. A solution of the differential equation $\frac{d^2x}{dt^2} + 10\frac{dx}{dt} + 25x = 0$ is _____

(A) $x = 3\cos 5t - 4\sin 5t$
(B) $x = 3e^{5t} - 4e^{-5t}$
(C) $x = (2 + 3t)\, e^{-5t}$
(D) $x = (2t - 3t^2)\, e^{-5t}$

16. A thin walled cylindrical shell, both ends closed, is subjected to an internal pressure. Ratio of longitudinal stress to circumferential stress developed in the wall of the cylinder is

(A) 0.5 (B) 1.0
(C) 2.0 (D) 4.0

17. The function of an interpolator in a CNC machine controller is to
(A) control speed
(B) coordinate feed rates of axes.
(C) control tool rapid approach speed
(D) perform miscellaneous functions.

18. 3 wire method is used to inspect a metric thread for its pitch diameter. If pitch of the thread is 1 mm and thread angle is 60°, diameter (in mm) of best wire is_.

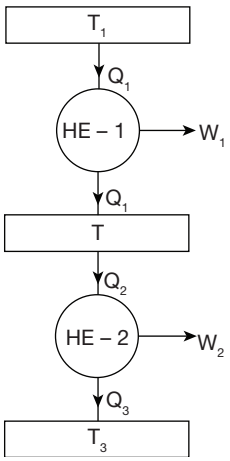
19. For a fully developed viscous flow through a circular pipe of diameter D, wall shear stress τ_w and pressure drop per unit length ΔP are related by

(A) $\tau_w = \frac{\Delta PD}{4}$ (B) $\tau_w = \frac{\Delta PD^2}{4}$

(C) $\tau_w = \frac{\Delta PD}{2}$ (D) $\tau_w = \frac{4\Delta P}{D}$

20. The degree of freedom for steam inside a boiler having a dryness fraction of 0.8 is
(A) zero (B) 1
(C) 2 (D) 3

21.



Two reversible heat engines *HE*- 1 and *HE*- 2 are connected in series and connected to thermal reservoirs at temperature T_1 = 1000 K and T_3 = 300 K as shown in figure. If the thermal efficiencies of the engines are same, the ratio of work done by the engines $\left(\frac{W_1}{W_2}\right)$ is_.

22. Relative humidity of air in a room is 75%. Pressure and dry bulb temperature are 1 bar and 30°C respectively. If saturated steam pressure at 30°C is 4250 N/m^2, specific humidity of air in the room in grams/kg of dry air is _____.

23. Two rods *A* and *B* of same material and equal length are subjected to identical tensile forces. If elastic strain energy stored in the rod *A* is 3 times to that in rod *B*, the ratio of diameter of *B* to diameter of *A* is _____.

24. Air of density 1.0 kg/m^3 enters a diesel engine cylinder at a steady rate of 20 × 10^{-3} kg/s. If the compression ratio and net work output are 21 and 10 kW respectively, the mean effective pressure (in kPa is).

25. Match the metal forming processes given in list I to similar processes given in list II

List I
P. Blanking
Q. Coining
R. Extrusion
S. Cup drawing

List II
1. Wire drawing
2. Punching
3. Embossing
4. Hot cupping
5. Bending

(A) $P-2\ Q-3\ R-4\ S-1$
(B) $P-3\ Q-2\ R-1\ S-5$
(C) $P-2\ Q-3\ R-1\ S-4$
(D) $P-2\ Q-3\ R-1\ S-5$

26. For a cutting tool workpiece combination when cutting speed was reduced to half, tool life increased 16 times. Value of index (n) in the Taylor's tool life equation for the tool-work piece combinations is .

27.

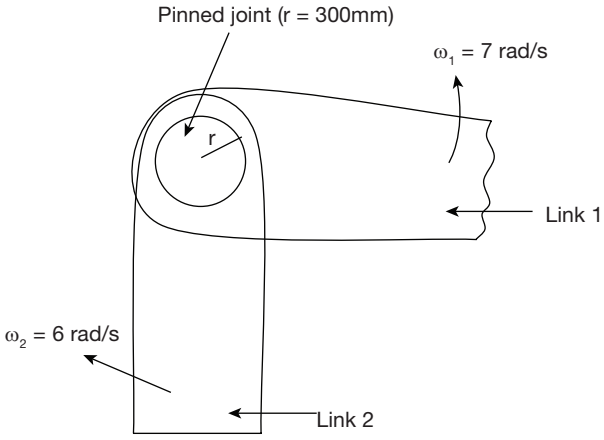


Figure shows a smooth pinned joint of pin radius r = 300 mm, connecting links 1 and 2 having angular velocities ω_1 = 7 rad/s counter clockwise and ω_2 = 6 rad/s clockwise as shown in figure. The velocity of rubbing at the pin joint (in m/s) is
(A) 0.3 (B) 1.95
(C) 3.9 (D) 7.80

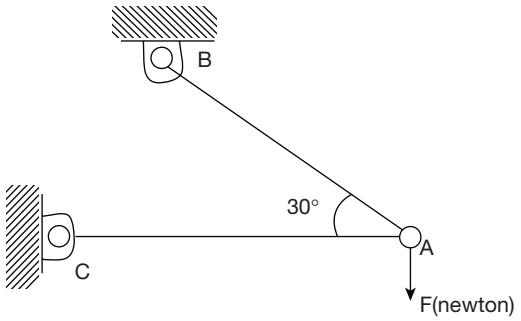
28. A man walking with constant speed takes 1.25 hour to travel a distance of 10 km with the wind blowing on his back. He take 1.80 hour to travel the same distance with the wind blowing on his face. If the speed and direction wind remains constant throughout, the ratio of speed of man to the speed of wind is.

29. When a fluid flows over a stationary solid boundary, with a main stream velocity U and if u is the velocity in the boundary layer formed at a distance y from the surface, the momentum thickness is given by the expression,

(A) $\int_0^{\delta}\left(1-\frac{u}{U}\right)dy$ (B) $\int_0^{\delta}\frac{u}{U}\left(1-\frac{u}{U}\right)dy$

(C) $\int_0^{\delta}\frac{u}{U}\left(1-\frac{u^2}{U^2}\right)dy$ (D) $\int_0^{\delta}\frac{u}{U}\left(1-\frac{u^3}{U^3}\right)dy$

30.



In the arrangement shown links AB and AC are uniform, made of same material, having same lengths and same areas of cross-section. When joint A is pulled down by a force F newton, $|\Delta L_1|$ *and* $|\Delta L_2|$ are the magnitudes of change in lengths of AB and AC respectively. Then, $\frac{|\Delta L_1|}{|\Delta L_2|}$ is equal to.

31. In the dimensional analysis of a physical phenomenon involving n variables, using Buckinghams π theorem equation is formed in terms of

(A) the repeating variables.
(B) geometric, kinematic and dynamic variables.
(C) $(n - m)$ dimensionless parameters
(D) $(n - m + 1)$ dimensionless parameters (m is the number of fundamental dimensions involved).

32. If σ_a = stress amplitude, σ_m = mean stress,
S_e = endurance limit,
S_{ut} = ultimate tensile stress and
FOS = factor of safety, then the equation for Gerber line is

(A) $\frac{\sigma_a}{S_e}+\frac{\sigma_m}{S_{yt}}=\frac{1}{FOS}$

(B) $\frac{\sigma_a}{S_e}+\frac{\sigma_m}{S_{ut}}=\frac{1}{FOS}$

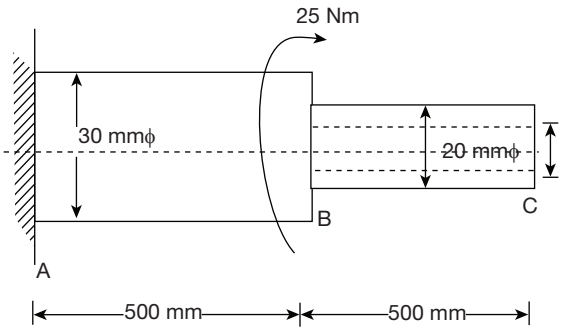
(C) $\frac{\sigma_a}{S_e}+\left(\frac{\sigma_m}{S_{ut}}\right)^2=\frac{1}{FOS}$

(D) $\frac{\sigma_a}{S_e}+\left(\frac{\sigma_m}{S_{ut}}\right)^2 FOS=\frac{1}{FOS}$

33. In gas welding of a job, a neutral *oxy*-acetylene flame was used. If the acetylene consumption was 8 litres, oxygen consumption from the cylinder (in litres) would be

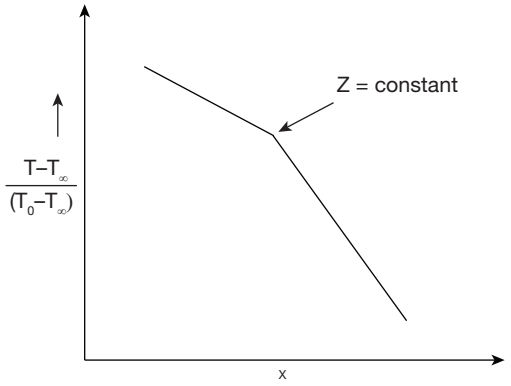
(A) 8 (B) 10
(C) 12 (D) 16

34.



A stepped shaft ABC, fixed at A and hollow at portion BC is subjected to a twisting moment of 25 Nm at B. Shaft dimensions are as shown in the figure. Shear modulus G = 75 GPa. The angle of twist at C (in degrees) is .

35. A uniform cylindrical rod at a temperature T_0 at time $t = 0$, is cooling in air at a free stream temperature T_∞. At time $t = t$, the centre of the rod is at a temperature T. Heisler chart gives the quantity $\frac{T-T_\infty}{T_0-T_\infty}$ on the ordinate as shown in figure.



The other quantities X(abscissa) and constant Z marked in the Heisler chart are respectively

(A) X = Product of Biot number and Fourier number, Z = Thermal conductivity.
(B) X = Fourier number and Z = Biot number
(C) X =Fourier number and $Z=\frac{1}{Biot\ number}$
(D) X = Biot number and Z = Fourier number

Questions 26 to 55 carry Two Marks each.

36. The maximum volume of a cylindrical cistern with open top of surface area (Area of bottom and side) 108π square feet is _____

(A) 216 π cubic feet (B) 432 πcubic feet
(C) 864 cubic feet (D) 1728 cubic feet

37. If the eigen values of a 3 × 3 matrix A are –1, 2 and 5 then the determinant of the inverse of the matrix $A + 2I_3$, where I_3 is the identity matrix of order 3 × 3 is _____

(A) $\frac{-1}{10}$ (B) $\frac{1}{10}$
(C) $\frac{-1}{28}$ (D) $\frac{1}{28}$

38. In a city, 60% of the youngsters are engineering graduates and 40% of the youngsters are science graduates. Among the engineering graduates, 45% are self employed where as 30% of the science graduates are self employed. If an youngster is selected at random from that city, who is self employed, then the probability that the person is a science graduate is _____

39. If $u(x, y) = \cos x \cdot \cosh y$ is the real part of an analytic function $f(z) = u(x, y) + i\,v(x, y)$ where $z = x + iy$ and $i = \sqrt{-1}$, then the imaginary part $v(x, y)$ of $f(z)$ is _____

(A) –cosx . coshy (B) sinx . sinhy
(C) –sinx . sinhy (D) cosx. sinhy

40. The length of the arc of the curve whose parametric equation is $x = \frac{t^2}{2}$,

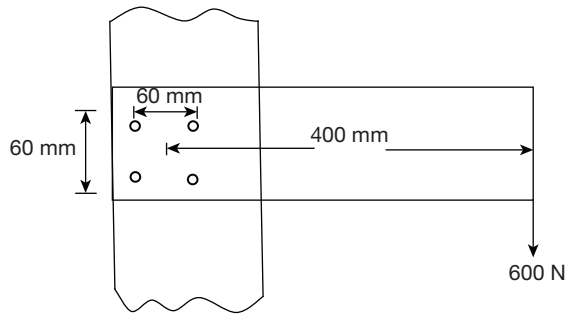
$y = \frac{1}{3}(2t + 1)^{3/2}$; $1 \le t \le 5$ is

(A) 12 (B) 14
(C) 16 (D) 18

41. A machine element is subjected to the following bi-axial state of stress;
σ_x = 100 MPa(tension),
σ_y = 20 MPa (compression); τ_{xy} = 45 MPa. If the shear strength of the material is
110 MPa, the factor of safety as per Tresca's maximum shear stress theory is

(A) 1.467 (B) 1.732
(C) 2.000 (D) 2.431

42.



A horizontal plate has been joined to a vertical post using four rivets arranged as shown in figure. The magnitude of the load on the worst loaded rivet (in N) is _____.

43. 1 kg of air (treat as ideal gas with constant specific heat capacities) flows through a turbine from an initial temperature of 700 K to a final temperature of 300 K as per the law $PV^{1.3}$ = constant. Given $\left(\frac{C_p}{C_v}\right)$ for air is 1.4 and R = 0.287 kJ/kg K for air, the change in specific entropy of air at the end of expansion(treat the expansion as a reversible process), expressed in kJ/kg K is. (kinetic energy and potential energy changes can be treated as negligible)

44. Two cubes of equal volume are cast from same material using sand casting process. If top and bottom faces of one of the cubes is completely insulated, the ratio of the solidification time of the insulated cube to that of the other cube is

(A) $\frac{3}{2}$ (B) $\frac{9}{4}$
(C) $\frac{4}{3}$ (D) $\frac{3}{4}$

45. Match the following pairs.

Model law		**Related dimensionless number**	
P.	Froude model law	I.	$\frac{V}{\sqrt{\frac{p}{\rho}}}$
Q.	Euler model law	II.	$\frac{V}{\sqrt{\frac{K}{\rho}}}$
R.	Weber model law	III.	$\frac{V}{\sqrt{Lg}}$
S.	Mach model law	IV.	$\frac{V}{\sqrt{\frac{\sigma}{\rho L}}}$

(A) $P-II$ $Q-IV$ $R-I$ $S-III$
(B) $P-II$ $Q-I$ $R-V$ $S-III$
(C) $P-III$ $Q-I$ $R-IV$ $S-II$
(D) $P-III$ $Q-IV$ $R-I$ $S-II$

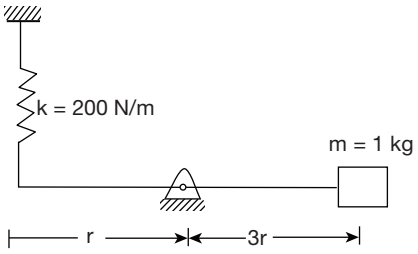
46. In a simple Brayton cycle; pressure ratio is 8 and temperatures at the entrance of compressor and turbine are 350 K and 1450 K respectively. Both the compressor and turbine have isentropic efficiencies 0.8. For the gas, ratio of specific heats is 1.4 and value of specific heat at constant pressure is
1 kJ/kg K. Neglecting changes in kinetic and potential energies, power required by the compressor in kW/kg of gas flow rate is_.

47. Oil of density 800 kg/m^3 flows through a horizontal venturimeter with inlet diameter 60 mm and throat

diameter 30 mm. Pressure gauges at inlet and throat read 400 kPa and 150 kPa respectively. Neglecting friction, velocity (in m/s) of the oil at the inlet is .

48. At a telephone booth average time between successive arrivals is 10 minutes. Mean length of a telephone call is 2.5 minutes. The arrivals can be considered as Poisson distributed and telephone call time is distributed exponentially. Probability that an arrival does not have to wait before service is .

49.



A thin uniform rod of mass 1 kg and length 4*r* is hinged at a distance r from one end as shown in figure and held horizontally. *A* point mass of 1 kg is at right end and a light spring of stiffness *k* = 200 N/m is at left end of rod. When the rod is slightly disturbed from its equilibrium portion, it undergoes vertical angular oscillations with a frequency (in rad/s) equal to

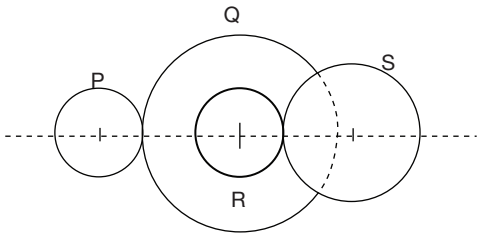
(A) 2.1 (B) 4.2
(C) 6.3 (D) 8.4

50. In a CAD package, mirror image of a 2*D* point *P*(4, 8) is to be obtained about a line passing through origin and making an angle 45° clockwise with *y*-axis. Coordinates of the image point is

(A) 6, 4 (B) 8, 4
(C) 6, –4 (D) 8, –4

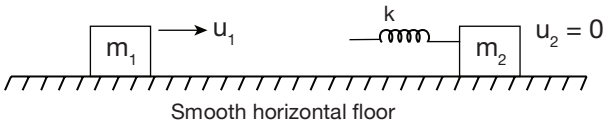
51. A round billet of 60 mm diameter and 100 mm length is extruded using direct extrusion process. If extrusion constant is 250 MPa and extrusion ratio is 4, the pressure (in MPa) on the ram is .

52.



A compound gear train with gears *P*, *Q*, *R* and *S* has number of teeth 20, 40, 15 and 20 respectively. Gears *Q* and *R* are mounted on the same shaft as shown in the figure. The diameter of gear *Q* is twice that of gear *R*. If the module of the gear *R* is 4 mm, the centre distance (in mm) between the gears *P* and *S* is .

53.

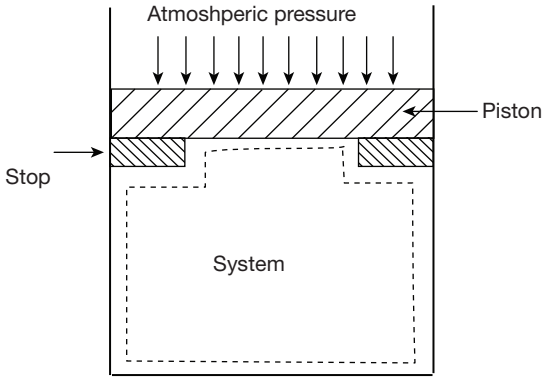


A block of mass m_2 = 5 kg is at rest on a smooth horizontal floor. The block has a light spring of stiffness k = 10 kN/m, projecting horizontally as shown in figure. A block m_1 of mass 5 kg is moving along a straight line with a speed of u_1 = 6 m/s and makes a perfectly elastic 1 dimensional collision with block m_2. The maximum compression (in millimeter) of the spring during the collision is .

54. A DC welding power source for arc welding has the characteristic $V + \frac{I}{3} = 80$ where V = voltage and I = current in ampere.

For maximum arc power at the electrode, voltage (in volts) should be set as_.

55.



In the figure shown, the system is a pure substance kept in a piston-cylinder arrangement. The system is initially a two phase mixture containing 1.5 kg of liquid and 0.06 kg of vapour at a pressure of 100 kPa. Initially, the piston rests on a set of stops. A pressure of 200 kPa is required to balance the weight of piston and the outside atmospheric pressure. Heat transfer taken place into the system until its volume increases by 65%. Heat transfer to the system takes place in such a manner that the piston, when allowed to move, does so in a very slow (quasi-static/quasi-equilibrium) process.

Specific volume of liquid(V_f) and vapour (V_g) phases, as well as values of saturation temperatures are given in table below.

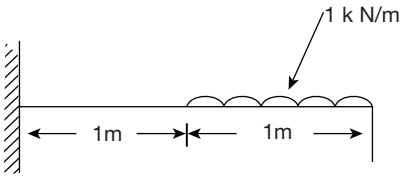
Pressure (kPa)	Saturation temperature, T_{sat} (°C)	V_f (m^3/kg)	V_g (m^3/kg)
100	100	0.001	0.1
200	200	0.0015	0.002

The work done by the system during the process(in J) is.

56. A riveting machine is driven by a constant torque 5 kW motor. Mass of flywheel and all moving parts is 200 kg and radius of gyration is 0.5 m. The riveting operation lasts 1 s and requires 15000 J of energy. During one rotation of shaft, one riveting operation is done. Speed of flywheel before riveting is 400 rpm. The speed of flywheel (in rpm) immediately after riveting is.

(A) 369 (B) 298
(C) 352 (D) 327

57.

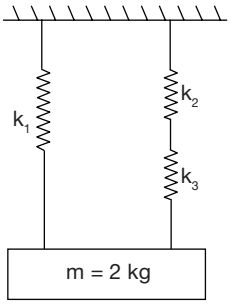


A cantilever beam of flexural rigidity 5×10^6 Nm^2 is loaded with a uniformly distributed load of 1 kN/m as shown in the figure. Deflection (in mm) at the free end of the beam is .

58. Pins of diameter $20^{+0.025}_{+0.005}$ mm are electroplated in a production shop. Thickness of the plating is 20 ± 2 micron. Size (in mm) of GO gauge used to inspect the plated pins is (Gauge tolerance may be neglected).

(A) 20.047 (B) 20.069
(C) 20.072 (D) 20.022

59.

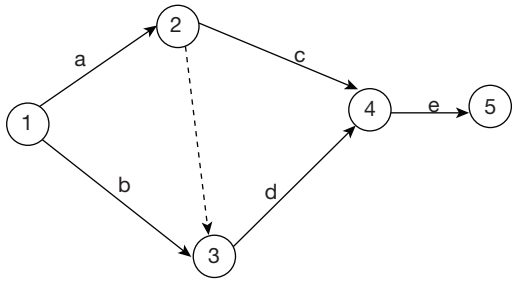


A mass of 2 kg is suspended by means of three springs as shown in figure. The spring constants k_1, k_2 and k_3 are respectively 1 kN/m, 2 kN/m and 3 kN/m. The natural frequency of vibration of system is approximately (in rad/second)

(A) 77.34 (B) 60.55
(C) 46.90 (D) 33.17

60. A flexible rotor-shaft system comprises of a 15 kg rotor disc placed in the middle of a massless shaft of diameter 30 mm and length 400 mm between bearings (shaft is being taken massless as the equivalent mass of the shaft is included in the rotor mass) mounted at the ends. The bearings are assumed to simulate simply supported boundary conditions. The shaft is made of steel for which the value of E is 2.1×10^{11}Pa. The critical speed of rotation of the shaft (in Hz) is ____.

61.



For the PERT network shown above, expected duration and standard deviation of activities are as shown below

Activity	Expected duration (days)	Standard deviation (days)
a	40	8
b	60	9
c	25	3
d	45	6
e	20	3

Standard deviation (in days) of the critical path is

(A) 11.225 (B) 18
(C) 17 (D) 10.440

62. The LMTD of a counterflow heat exchanger is 26°C. The cold fluid enters at 20°C and the hot fluid enters at 100°C. The mass flow rate of the cold fluid is twice that of the hot fluid. The specific heat at constant pressure of the hot fluid is twice that of the cold fluid. The ratio of the exit temperature of cold fluid to the exit temperature of hot fluid is

(A) 1.61 (B) 1.73
(C) 1.52 (D) 1.00

63. For a fluid flow over a flat plate, velocity (u) and boundary layer thickness (δ) can be expressed as

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2 ; \quad \delta = \frac{5.48x}{\sqrt{R_{ex}}}$$

If the free stream velocity (U) is 2 m/s and kinematic viscosity and density of the fluid are 1.6×10^{-5} m^2/s and 1.25 kg/m^3 respectively, wall shear stress (in __ $\times 10^{-3}$ N/m^2) at $x = 1$ m is_.

64. The streamline function in a two dimensional flow field is given by $\psi = x^2 - y^2$ The magnitude of velocity at point (1, 2) is _.

65. Following are the data in an orthogonal cutting operation.
Rake angle = 15°
Cutting speed = 20 m/min
Chip thickness = 0.7 mm
Width of cut = 4.5 mm
Cutting ratio = 0.714
Assuming Merchant's theory, coefficient of friction at the tool-chip interface is ____.

Answer Keys

1. B	**2.** B	**3.** C	**4.** D	**5.** A	**6.** 68	**7.** C	**8.** A	**9.** C	**10.** D
11. A	**12.** 3	**13.** 1.8	**14.** D	**15.** C	**16.** A	**17.** B	**18.** 0.570 to 0.585		**19.** A
20. B	**21.** 1.8000 to 1.8500		**22.** 20 to 21		**23.** 1.730 to 1.735		**24.** 524 to 526		**25.** C
26. 0.25	**27.** C	**28.** 5.525 to 5.565		**29.** B	**30.** 1.145 to 1.165		**31.** C	**32.** D	**33.** A
34. 0.119 to 0.121		**35.** C	**36.** A	**37.** D	**38.** 0.29 to 0.31		**39.** C	**40.** C	**41.** A
42. 1515 to 1530		**43.** 0.2015 to 0.2035		**44.** B	**45.** C	**46.** 354.5 to 355.5		**47.** 6.4 to 6.5	
48. 0.75	**49.** B	**50.** B	**51.** 346 to 347		**52.** 159.5 to 160.5		**53.** 94.50 to 95.25		**54.** 40
55. 970 to 980		**56.** C	**57.** 0.33 to 0.35		**58.** B	**59.** D	**60.** 102.800 to 103.850		**61.** A
62. A	**63.** 5.15 to 5.18		**64.** 4.46 to 4.48		**65.** 0.45 to 0.46				

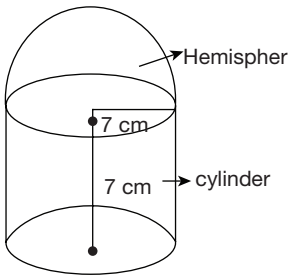
Hints and Explanations

Solutions for questions 1 to 10:

1. 'Toxicity' gives the clue to the correct answer. Something which is toxic is detrimental (harmful). Hence it is logical to say that despite its known 'toxicity', lead continues to be used to the detriment of human and environmental health. The word solace (relief; comfort) runs contrary to what is stated in the sentence. The word chagrin (annoyance) is too mild to be used for something which is toxic. The word impediment (hindrance; obstacle) does not make sense here.

Choice (B)

2.



Volume of the hemisphere = $\left(\frac{1}{2}\right)\left(\frac{4}{3}\right)\pi r^3$

$= \left(\frac{2}{3}\right)(\pi)\left(7^3\right)$

Volume of the cylinder = $\pi r^2 h = 7^3\pi$

Total volume = $(\pi)7^3\left[1+\frac{2}{3}\right] = \frac{5\pi}{3}(7^3)$ Choice (B)

3. The study of man is called Anthropology. Form the point, "Anthropology is called ornithology", we can say that Ornithology is the word that is used to refer to Anthropology. Choice (C)

4. Biology is the study of life, Mythology is the study of myths. Archaeology is not the study of antiques, it is the specific study of historic or prehistoric peoples and their cultures by analysis of their antifacts, inscriptions, monuments etc, especially those that have been excavated. Astrology is the study that assumes and attempts to interpret the influence of heavenly bodies on human affairs. Cosmetology is the art or profession of applying cosmetics. Only option D expresses a relationship which is similar to that expressed by the headwords.

Choice (D)

5. The reference is to a specific monsoon hence, the definite article 'the' is more appropriate in the first blank. The present perfect continuous tense 'has been showing' is apt in the second blank because here, the reference is to a trend which started sometime in the past and is still continuing. In the third blank, the reference is to something which took place during a specific time period. This is best denoted using the preposition 'over'. The definite article is required in the fourth blank because the reference is to a particular subcontinent.

Choice (A)

6. h (12, 11, 8, 16) = 12 × 11 > 8 × 16

132 > 128

Remainder when 132 is divided by 128 = 4.

$fg\,(h(12,11,8,16),17,9,16) = fg(4,17,9,16)$

$= f\,(4,17,9,16) \times g\,(4,17,9,16) = 17 \times 4 = 68.$

Ans:68

7. Options A and B run contrary to what is stated. Option D is incorrect because it is not mentioned that the brain and the lymphatic system are connected 'indirectly'. Only option C can be logically inferred from the given sentence. Choice (C)

8. Only statement (i) can be inferred from the given passage. It cannot be inferred from the passage that the government does not consider cyber threats as serious as other security threats. Options (iii) and (iv) are illogicall. Choice (A)

9. There are 33 instances of students leaving out a question (The sum of the 4 numbers in column 5) Exactly 5 students attempted all 4 questions. We distribute there 33 instances over all the remaining 25 students there would be 8 more instances. We can collect them to at the most 8 students.

∴ The maximum possible number of students who left out at least 2 questions is 8.

Choice (C)

10. All I, II and III are appropriate and apt courses of action. Choice (D)

11. Statements given in options (B), (C) and (D) are standard results and are true for every real skew-symmetric matrix A.
Counter Example for option (A):
Take $A = \begin{bmatrix} 0 & 3 \\ -3 & 0 \end{bmatrix} \Rightarrow \text{Det } A = 9 \neq 0 \Rightarrow$ Product of eigen values of A is NOT zero. Choice (A)

12. We have $\underset{x\to 3}{Lim}\ \log_5\left[4x^3 + \sqrt{(3x^4 + 5x^2 + 1)}\right]$

$= \log_5\left(\underset{x\to 3}{Lim}\left[4x^3 + \sqrt{(3x^4 + 5x^2 + 1)}\right]\right.$

$= \log_5(108 + \sqrt{289})$

$= \log_5 125 = \log_5 5^3 = 3$ Answer: 3

13. Let $f(x) = x^3 + x^2 + 4x + 4 = 0$
One can observe that $x = -1$ is a real root of $f(x) = 0$
and $f(x) = (x+1)(x^2 + 4) = 0$
$\therefore$ x = –1 is the only real root of $f(x) = 0$
$f'(x) = 3x^2 + 2x + 4$
Given $x_0 = 2$
$\therefore$ $f(x_0) = f(2) = 24$ and $f'(x_0) = f'(2) = 20$
By Newton-Raphson method the root of $f(x) = 0$ after first iteration is

$$x_1 = x_0 - \frac{f(x_0)}{f(x_0)} = 2 - \frac{24}{20}$$

$$= 2 - \frac{6}{5} = \frac{4}{5}$$

$x_1 = 0.8$
$\therefore$ The absolute error = |–1 – 0.8| = 1.8.
Answer: 1.8

14. We know that the Fourier series expansion of a periodic function $f(x)$ of period 2a in $[-a, a]$ will have only sine terms if $f(x)$ is an odd function. Among the functions given in the options, the function given only in option (*D*) only is odd.
$\therefore$ Its Fourier series expansion will consist of only sine terms. Choice (D)

15. Given differential equation is

$$\frac{d^2x}{dt^2} + 10\frac{dx}{dt} + 25x = 0 \qquad \rightarrow (1)$$

The auxiliary equation of (1) is
$D^2 + 10D + 25 = 0$
$\Rightarrow$ $(D + 5)^2 = 0$
$\Rightarrow$ $D = -5, -5$
$\therefore$ The general solution of (1) is
$x = (c_1 + c_2 t)e^{-5t}$ $\rightarrow (2)$
by taking $c_1 = 2$ and $c_2 = 3$ in (2),
we can get a solution of (1) as
$x = (2 + 3t)e^{-5t}$ Choice (C)

16. Longitudinal stress $\sigma_L = \frac{pd}{4t}$

Circumferential stress $\sigma_C = \frac{pd}{2t}$

$\sigma_L / \sigma_C = 0.5$ Choice (A)

17. Choice (B)

18. Diameter of the best wire = $\frac{p}{2}\sec\left(\frac{a}{2}\right)$

$= \frac{1}{2}\sec\left(\frac{60}{2}\right) = 0.5774$ mm Answer 0.570 to 0.585

19. $\tau_w = \frac{\partial p}{\partial x}\frac{R}{2} = \frac{\Delta P}{L}\frac{D}{4}$

For unit length, $\tau_w = \frac{\Delta PD}{4}$ Choice (A)

20. The degree of freedom for wet steam is 1.
Using Gibb's phase rule, $P + F = C + 2$
$P = 2$(two phases), $C = 1$(only water)
$\Rightarrow$ $F = C + 2 - P = 1 + 2 - 2 = 1$
$\therefore$ Degree of freedom, F = 1 Choice (B)

21. $\eta_1 = 1 - \frac{T}{T_1}$

$\eta_2 = 1 - \frac{T_3}{T}$

$\eta_1 = \eta_2 \Rightarrow 1 - \frac{T}{T_1} = 1 - \frac{T_3}{T} \Rightarrow T = \sqrt{T_1 T_3}$

$\therefore$ $T = \sqrt{1000 \times 300} = 547.72$ K
If Q is heat drawn at T_1, work done by HE- 1 is

$$W_1 = Q\eta_1 = Q\left[1 - \frac{547.72}{1000}\right] = 0.45228Q$$

$\therefore$ Heat rejected $Q_2 = Q - W_1 = 0.54772Q$
$\therefore$ Work done by *HE*-2, $W_2 = Q_2\eta_2$
$= 0.54772\, Q\eta_2$

$$\therefore \quad \frac{W_1}{W_2} = \frac{Q\eta_1}{0.54772Q\eta_2} = \frac{1}{0.54772}$$

$= 1.8258 (\because \eta_1 = \eta_2)$
Answer 1.8000 to 1.8500

22. Relative humidity = $\frac{p_v}{p_{vs}}$

$= \frac{p_v}{4250} = 0.75$

$\Rightarrow$ $p_v = 4250 \times 0.75 = 3187.5$

Specific humidity = $0.622\frac{p_v}{p - p_v}$

$$= 0.622\left[\frac{3187.5}{10^5 - 3187.5}\right]$$

= 0.02048 kg/kg of dry air

= 20.48 gm/kg of dry air Answer 20 to 21

23. Strain energy stored $(SE) = \frac{\sigma^2}{2E} \times Volume$

$$= \frac{\left(\frac{P}{A}\right)^2}{2E} \times A \times L = \frac{P^2 L}{2AE}$$

$$\frac{(SE)_A}{(SE)_B} = \frac{P^2 L}{2A_A E} \times \frac{2A_B E}{P^2 L} = \frac{A_B}{A_A} = \frac{D_B^2}{D_A^2}$$

$$\Rightarrow \quad \left(\frac{D_B}{D_A}\right)^2 = 3$$

$$\Rightarrow \quad \frac{D_B}{D_A} = \sqrt{3} = 1.732$$ Answer 1.730 to 1.735

24. Air intake rate $(V) = 20 \times 10^{-3}$ kg/s

$= 20 \times 10^{-3}$ m³/s [$\because \rho = 1$ kg/m³]

Work output = 10 kW

Compression ratio $r = 21$

$$Swept\ volume/_{s} = V\left(1 - \frac{1}{r}\right)$$

$$\text{Mean effective pressure} = \frac{Work\ output}{Swept\ volume}$$

$$= \frac{10}{20 \times 10^{-3}\left(1 - \frac{1}{21}\right)} = 525 \text{ kPa}$$ Answer 524 to 526

25. Choice (C)

26. Taylor's tool life equation is $VT^n = C$

or $V_1 T_1^n = V_2 T_2^n$

$$\therefore \quad V_1 T_1^n = \frac{V_1}{2}(16T_1)^n$$

$$\Rightarrow \quad T_1^n = \frac{1}{2}(16T_1)^n$$

$\Rightarrow \quad 2 = 16^n \Rightarrow \log 2 = n \log 16$

$\Rightarrow \quad n = 0.25$ Answer 0.25

27. Velocity of rubbing $= r(\omega_1 + \omega_2)$

= 0.3[7 + 6] = 3.9 m/s Choice(C)

28. $(V_{man} + V_{wind})t_1 = S_1$

$$\Rightarrow \quad V_{man} + V_{wind} = \frac{S_1}{t_1} = \frac{10}{1.25} = 8 \qquad \rightarrow \text{(ii)}$$

$(V_{man} - V_{wind})t_2 = S_2$

$$\Rightarrow \quad V_{man} - V_{wind} = \frac{S_2}{t_2} = \frac{10}{1.8} = 5.56 \qquad \rightarrow \text{(ii)}$$

(i) + (ii) $\Rightarrow 2V_{man} = 13.56$ $V_{man} = 6.78$

$\therefore \quad V_{wind} = 8 - V_{man} = 8 - 6.78 = 1.22$

$$\therefore \quad \frac{V_{man}}{V_{wind}} = \frac{6.78}{1.22} = 5.557$$ Answer: 5.525 to 5.565

29. Choice (B)

30. $F_{AB} \sin 30° = F \Rightarrow F_{AB} = 2F$ $\rightarrow$(i)

$F_{AB} \cos 30 = F_{AC} \Rightarrow F_{AC} = \sqrt{3}\,F$ $\rightarrow$ (ii)

$$\Delta L_1 = \frac{F_{AB} L}{AE}\ ;\ \Delta L_2 = \frac{F_{AC} L}{AE}$$

$$\therefore \quad \frac{\Delta L_1}{\Delta L_2} = \frac{F_{AB}}{F_{AC}} = \frac{2F}{\sqrt{3}F} = \frac{2}{\sqrt{3}} = 1.155$$

Answer: 1.145 to 1.165

31. Choice (C)

32. The equation for Gerber line (which is elliptical) is

$$\frac{\sigma_a}{S_e} + \left(\frac{\sigma_m}{S_{ut}}\right)^2 FOS = \frac{1}{FOS}$$ Choice (D)

33. Choice (A)

34. Angle of twist at C = Angle of twist at B

$$\Rightarrow \quad \theta = \frac{TL}{GJ} = \frac{25 \times 0.5 \times 32}{75 \times 10^9 \times \pi \times (0.03)^4}$$

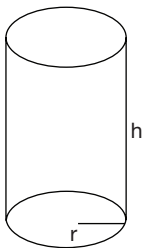
$= 2.0959 \times 10^{-3}$ radian $= 0.12°$

Answer 0.119 to 0.121

35. Abscissa X = Fourier number $= \frac{\alpha t}{L_c^2}$ and

$$Z = \frac{1}{Biot\ number} = \frac{k}{hL_c}$$ Choice (C)

36.



Let r and h be the radius and height of the cylindrical cistern with surface = 108π sq. feet

$\therefore \quad 2\pi rh + \pi r^2 = 108$

$\Rightarrow \quad 2rh = 108 - r^2$

$$\Rightarrow \quad h = \frac{108 - r^2}{2r} \qquad \rightarrow (1)$$

Volume of the cylindrical cistern $= C = \pi r^2 h$

$$= \pi r^2 \left(\frac{108 - r^2}{2r}\right)$$

$$\therefore \quad V = \frac{\pi}{2}(108r - r^3) \qquad \rightarrow (2)$$

$$\text{Let } f(r) = \frac{\pi}{2}(108r - r^3)$$

$\therefore$ We have to find the maximum value of V.

$f'(r) = \frac{\pi}{2}(108 - 3r^2)$

$f'(r) = 0 \Rightarrow \frac{\pi}{2}(108 - 3r^2) = 0$

$\Rightarrow$ $108 - 3r^2 = 0 \Rightarrow r^2 = 36 \Rightarrow r = 6$

And $f''(r) = -3\pi r < 0$ for $r = 6$

$\therefore$ f(r) is maximum at $r = 6$

Hence the maximum volume of the cistern

$= V$ at $x = 6$

$= \frac{\pi}{2}(108 \times 6 - 6^3)$

$= 216\pi$ cubic feet. Choice (A)

37. Given –1, 2 and 5 are the eigen values of A.

$\therefore$ $-1 + 2$, $2 + 2$ and $5 + 2$ are the eigen values of $A + 2I_3$

i.e., 1, 4 and 7 are the eigen values of $A + 2I_3$

$\therefore$ Det $(A + 2I_3) = |A + 2I_3|$ = Product of the eigen values of $A + 2I_3 = 1 \times 4 \times 7 = 28$

$\Rightarrow$ Determinant of inverse of $A + 2I_3$

$= |(A + 2I_3)^{-1}| = \frac{1}{|A+2I_3|} = \frac{1}{28}$ Choice (D)

38. Let B_1 and B_2 denote the events of selecting an engineering graduate and a science graduate respectively.

Let A be the event of selecting a youngster who is self employed.

$\therefore$ $P(B_1) = \frac{60}{100} = 0.6$, $P(B_2) = \frac{40}{100} = 0.4$

$P(A/B_1) = \frac{45}{100} = 0.45$ and $P(A/B_2) = \frac{30}{100} = 0.3$

If the youngster selected is found to be self employed, then the probability that the person is a science graduate

$$= P(B_2/A) = \frac{P(B_2).P\left(\frac{A}{B_2}\right)}{P(B_1).P\left(\frac{A}{B_1}\right) + P(B_2).P\left(\frac{A}{B_2}\right)}$$

(By Baye's Theorem)

$= \frac{0.4 \times 0.3}{(0.6 \times 0.45) + (0.4 \times 0.3)} = \frac{12}{39}$

$= 0.3077$ (Answer: 0.29 to 0.31]

39. Given $f(z) = u(x, y) + i\, v(x, y)$ is analytic and $u(x, y) = \cos x . \cosh y$.

$\therefore$ $\frac{\partial u}{\partial x} = u_x = -\sin x . \cosh y$

and $\frac{\partial u}{\partial y} = u_y = \cos x . \sin hy$

As $f(z)$ is analytic, $u(x, y)$ and $v(x, y)$ will satisfy Cauchy – Reimann equations.

i.e., $u_x = v_y$ and $v_x = -u_y \rightarrow (1)$

we know that $dv = \frac{\partial v}{\partial x}dx + \frac{\partial V}{\partial y}dy$

$= v_x\, dx + v_y\, dy$

$= -u_y dx + u_x dy$ (From (1))

$= -(\cos x . \sin hy)\, dx + (-\sin x . \cos hy)\, dy$

$\therefore$ $dv = -\cos x . \sin hy\, dx - \sin x . \cosh y\, dy$

$= -d(\sin x . \sin hy)$

$\Rightarrow$ $v(x, y) = -\sin x . \sin hy$ Choice (C)

40. Given curve is $x = t^2/2$ and $y = \frac{1}{3}(2t + 1)^{3/2}$; $1 \le t \le 5$

$\therefore$ $\frac{dx}{dt} = t$ and $\frac{dy}{dt} = (2t + 1)^{1/2}$

The length of arc of the curve from $t = 1$ to $t = 5$

Is $\int_1^5 \sqrt{\left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2\right]}\, dt$

$= \int_1^5 \sqrt{\left[t^2 + \left((2t+1)^{1/2}\right)^2\right]}\, dt$

$= \int_1^5 \sqrt{(t^2 + 2t + 1)}\, dt = \int_1^5 \sqrt{(t+1)^2}\, dt$

$= \left[\frac{t^2}{2} + t\right]_1^5 = 16$ Choice (C)

41. $\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}}$

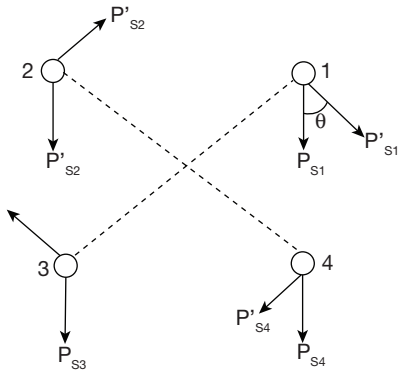
$= \sqrt{\left[\frac{100 - (-20)}{2}\right]^2 + 45^2} = \sqrt{60^2 + 45^2} = 75$ MPa

According to maximum shear stress theory,

$\tau_{max} = \frac{S_{sy}}{FOS} \rightarrow FOS = \frac{S_{sy}}{\tau_{max}}$

$\therefore$ FOS $= \frac{110}{75} = 1.467$ Choice (A)

42.



The primary shear load (P_s) on each rivet is

$$P_s = \frac{600}{4} = 150\text{ N}$$

$$\therefore \quad P_{s_1} = P_{s_2} = P_{s_3} = P_{s_4} = 150\text{ N}$$

For each bolt, distance from CG is

$$r_1 = r_2 = r_3 = r_4 = r = \frac{60\sqrt{2}}{2}\text{mm} = 30\sqrt{2}\text{mm}$$

$= 42.426$ mm $= 0.04243$ m

Secondary shear load on each bolt

$$P'_{s_1} = P'_{s_2} = P'_{s_3} = P'_{s_4} = \frac{(We)r}{\left[r_1^2 + r_2^2 + r_3^2 + r_4^2\right]}$$

$$= \frac{Wer}{4r^2} = \frac{We}{4r} = \frac{600 \times 0.4}{4 \times 0.04243} = 1414.10\text{ N}$$

Bolts 1 and 4 are the worst loaded bolts.

$$\therefore \quad P_{\max} = \sqrt{P_{s_1}^2 + \left(P'_{s_1}\right)^2 + 2P_{s_1}P'_{s_1}\cos 45°}$$

$$= \sqrt{(150)^2 + (1414.10)^2 + 2 \times 150 \times 1414.10 \times \cos 45°}$$

$$= \sqrt{2322154.72} = 1523.86\text{ N}$$

Answer: 1515 to 1530

43. Work done during expansion $W = \frac{n}{(n-1)}mR(T_1 - T_2)$

For polytropic process,

Heat supplied, $Q = \Delta H + W$

$$= mC_p(T_2 - T_1) + \frac{n}{(n-1)}mR(T_1 - T_2)$$

$$= mR(T_1 - T_2)\left[\frac{n}{(n-1)} - \frac{\gamma}{(\gamma-1)}\right] \qquad \left[\because C_p = \frac{\gamma R}{(\gamma-1)}\right]$$

$$= \frac{(\gamma - n)}{(\gamma-1)(n-1)}mR(T_1 - T_2)$$

$$\Rightarrow \quad Q = \frac{-(\gamma-n)mR(T_2 - T_1)}{(\gamma-1)(n-1)}$$

$$= \frac{(n-\gamma)mR(T_2 - T_1)}{(\gamma-1)(n-1)}$$

$$\Rightarrow \quad \delta Q = \frac{(n-\gamma)mR}{(\gamma-1)(n-1)}dT$$

$$\therefore \quad ds = \frac{\delta Q}{T} = \frac{(n-\gamma)mR}{(\gamma-1)(n-1)}\frac{dT}{T}$$

$$\Rightarrow \quad ds = \frac{\delta Q}{mT} = \frac{(n-\gamma)R}{(\gamma-1)(n-1)}\frac{dT}{T}$$

$$S_2 - S_1 = \int_1^2 ds = \int_{T_1}^{T_2} \frac{(n-\gamma)R}{(\gamma-1)(n-1)}\frac{dT}{T}$$

$$= \frac{(n-\gamma)R}{(\gamma-1)(n-1)}\ln\frac{T_2}{T_1}$$

$$= \frac{(1.3-1.4)\times 0.287}{(1.4-1)(1.3-1)}\ln\left(\frac{300}{700}\right)$$

$$= \frac{-0.1 \times 0.287}{0.4 \times 0.3} \times -0.8473 = +0.2026\text{ kJ/kg K}$$

Answer 0.2015 to 0.2035

44. Solidification time $t = C\left(\frac{V}{A}\right)^2$ where V = Volume

A = Surface area losing heat C = Constant

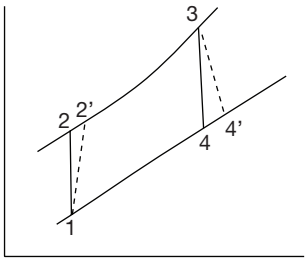
$\therefore$ Let t_1 be the solidification time of the insulated cube.

$$\frac{t_1}{t_2} = \left(\frac{A_2}{A_1}\right)^2 \text{ as } V \text{ is } = \left(\frac{6}{4}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$$

Choice (B)

45. Choice(C)

46.



$T_1 = 350\ K$ $C_p = 1$ kJ/kg K

$T_3 = 1450\ K$ $\gamma = 1.4$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 8^{\frac{0.4}{1.4}}$$

$$\Rightarrow \quad T_2 = 350 \times 8^{\frac{0.4}{1.4}} = 634\ K$$

Isentropic efficiency $\frac{T_2 - T_1}{T'_2 - T_1} = 0.8$

$$\Rightarrow \quad \frac{634 - 350}{T'_2 - 350} = 0.8$$

$$\Rightarrow \quad T'_2 = 705\ K$$

Power required by the compressor $= C_p(T'_2 - T_1)$

$= 1 \times (705 - 350) = 355$ kW/kg

Answer 354.5 to 355.5

47. $\rho = 800$ kg/m^3

$d_1 = 60$ mm, $d_2 = 30$ mm

$p_1 = 400$ kPa, $p_2 = 150$ kPa.

Applying Bernoulli's theorem,

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} = \frac{p_2}{\rho g} + \frac{v_2^2}{2g}$$

$$\Rightarrow \quad \frac{v_2^2 - v_1^2}{2} = \frac{p_1 - p_2}{\rho}$$

$$\Rightarrow \quad v_2^2 - v_1^2 = \frac{2}{\rho}(p_1 - p_2) = \frac{2\times10^3}{800}(400-150)$$

$$\Rightarrow \quad v_2^2 - v_1^2 = 625 \qquad \text{.....(1)}$$

Applying continuity equation, $a_1v_1 = a_2v_2$

$$\Rightarrow \quad d_1^2 v_1 = d_2^2 v_2$$

$$\Rightarrow \quad v_2 = \left(\frac{d_1}{d_2}\right)^2 v_1$$

$$\Rightarrow \quad v_2 = 4v_1 \qquad \text{.....(2)}$$

From (1) and (2) $(4v_1)^2 - v_1^2 = 625$

$$\Rightarrow \quad 15v_1^2 = 625$$

$$\Rightarrow \quad v_1 = 6.455 \text{ m/s}$$ Answer 6.4 to 6.5

48. Arrival rate $\lambda = \frac{1}{10} = 0.1/\text{min}$

Service rate $\mu = \frac{1}{2.5} = 0.4/\text{min}$

Probability that an arrival has to wait

$$= \rho = \frac{\lambda}{\mu} = \frac{0.1}{0.4} = 0.25$$

Probability that an arrival does not have to wait = 1 – ρ
= 1 – 0.25 = 0.75 Answer 0.75

49. $I_{\text{rod}} = \frac{ml^2}{12} + md^2 = \frac{m(4r)^2}{12} + m(2r-r)^2$

$$= \frac{4}{3}mr^2 + mr^2 = \frac{7}{3}mr^2 = \frac{7}{3}r^2$$

($\because$ m = 1 kg for rod)

$I_{\text{mass}} = m(3r)^2 = 1 \times 9r^2 = 9r^2$

($\because$ m = 1 kg for point mass)

$\therefore$ Total $I = \frac{7}{3}r^2 + 9r^2 = \frac{34}{3}r^2$

Let the rod undergo a small angular displacement θ from its mean position.

Inertial torque, $T_i = I\alpha = I\ddot{\theta} = \frac{34}{3}r^2\ddot{\theta}$

Restoring force = k(rθ)

Restoring torque, $T_r = k(r\theta)r = kr^2\theta = 200r^2\theta$

As per D'Alembert's, principle, $T_i + T_r = 0$

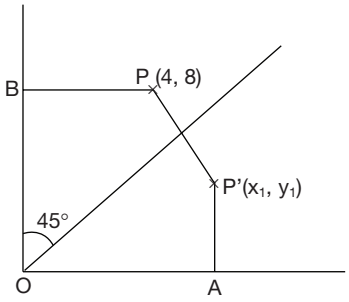
$$\Rightarrow \quad \frac{34}{3}r^2\ddot{\theta} + 200r^2\theta = 0$$

$$\Rightarrow \quad \ddot{\theta} = \frac{-200\times3}{34}\theta \Rightarrow \text{SHM}$$

$$\therefore \quad \omega^2 = \frac{200\times3}{34}$$

$$\Rightarrow \quad \omega = \sqrt{\frac{200\times3}{34}} = 4.2 \text{ rad/s}$$ Choice (B)

50.



Let $P'(x_1,y_1)$ be the mirror image of $P(4,8)$ about line OC

Due to symmetry, $OA = OB$ and $AP' = BP$

i.e., $x_1 = 8$ and $y_1 = 4$

$\therefore$ Coordinates of point P' is (8, 4). Choice (B)

51. $L_0 = 100$ mm

$d_0 = 60$ mm

$K = 250$ MPa

Extrusion ratio $\frac{A_0}{A_1} = 4$

Extrusion force $F = KA_0\,\ell n\left(\frac{A_0}{A_1}\right)$

Pressure on ram $= \frac{F}{A_0} = K\ell n\left(\frac{A_0}{A_1}\right) = 250\ \ell n\,4$

= 346.57 MPa Answer 346 to 347

52. Given $Z_p = 20$, $Z_Q = 40$, $Z_R = 15$ and $Z_S = 20$

Diameter of Q = 2 × Diameter of R

$\therefore$ $m_QZ_Q = 2m_RZ_R$; Given $m_R = 4$ mm

$$\therefore \quad m_Q = 2m_R\frac{Z_R}{Z_Q} = 2\times4\times\frac{15}{40} = 3\,\text{mm}$$

$m_P = m_Q = 3$ mm and $m_S = m_R = 4$ mm

$$\text{Radius} = \frac{\text{Module} \times \text{no of teeth}}{2}$$

$$\therefore \quad d = R_P + R_Q + R_R + R_S$$

$$= \frac{(m_PZ_P + m_QZ_Q + m_RZ_R + m_sZ_s)}{2}$$

$$= \frac{3(Z_P + Z_Q) + 4(Z_R + Z_S)}{2}$$

$$= \frac{3(Z_P + Z_Q) + 4(Z_R + Z_S)}{2}$$

$$= \frac{3(20+40) + 4(15+20)}{2}$$

$$= \frac{180+140}{2} = 160 \text{ mm}$$ Ans:159.5 to 160.5

53. Velocity of centre of mass of system,

$$V_{CM} = \frac{m_1u_1 + m_2u_2}{(m_1+m_2)} = \frac{(5\times6)+0}{(5+5)} = 3 \text{ m/s}$$

When both the blocks are moving with the same speed, equal to the velocity of centre of mass, the compression in spring will be maximum.
From energy conservation,

$$\frac{1}{2}m_1u_1^2 = \frac{1}{2}m_1v_{cm}^2 + \frac{1}{2}m_2v_{cm}^2 + \frac{1}{2}kx_{MAX}^2$$

$$\Rightarrow \quad 5 \times 6^2 = 5 \times 3^2 + 5 \times 3^2 + 10 \times 1000 \times x_{MAX}^2$$

$$\Rightarrow \quad 180 = 45 + 45 + 10000x_{MAX}^2$$

$$\Rightarrow \quad x_{MAX} = \sqrt{\frac{90}{10000}} = 0.09487 \text{ m} = 94.87 \text{ mm}$$

Answer 94.50 to 95.25

54. $V + \frac{I}{3} = 80$

i.e., $3V + I = 240$
$\Rightarrow \quad I = 240 - 3V$
$\Rightarrow$ Power $P = VI = 240V - 3V^2$
For maximum power, $\frac{dP}{dV} = 0$
i.e., $240 - 6V = 0$
$\Rightarrow \quad 6V = 240$
$\Rightarrow \quad V = 40$ Volts Answer 40

55. At 100 kPa, volume of water
= mass ×specific volume
$= 1.5 \times 0.001 = 0.0015 \text{ m}^3$
At 100 kPa, volume of vapour
= mass × specific volume
$= 0.06 \times 0.1 = 0.006 \text{m}^3$
Initial volume, $V_1 = 0.0015 + 0.006 = 0.0075 \text{ m}^3$
Final volume, $V_2 = 1.65V_1$
$= 1.65 \times 0.0075 = 0.012375 \ m^3$
$\therefore$ Change in volume, $\Delta V = V_2 - V_1 = 0.004575 \text{ m}^3$
During the time, pressure remains constant at 200 kPa .
$\therefore$ Work done, $W = pdv$
$= 200 \times 0.004875$ kJ
$= 0.975$ kJ $= 975$ J Answer: 970 to 980

56. Moment of inertia of flywheel, $I = mk^2$
$= 200 \times (0.5)^2 = 50 \text{ kg m}^2$

Initial angular velocity $\omega_1 = \frac{2\pi N_1}{60} = \frac{2\pi \times 400}{60}$ rad/s

$= 41.888$ rad/s
Time for riveting $t = 1$s
$\therefore$ Energy supplied by flywheel $= E - E_1$
$= 15000 - 5000 = 10{,}000 \ J$
If ω_2 is the angular velocity immediately after punching, $\frac{1}{2}I\left(\omega_1^2 - \omega_2^2\right) = 10{,}000$

$$\Rightarrow \quad \omega_1^2 - \omega_2^2 = \frac{2 \times 10{,}000}{50} = 400$$

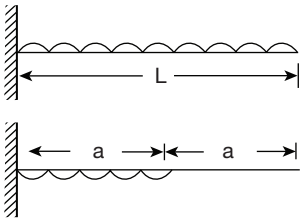
$$\therefore \quad \omega_2^2 = \omega_1^2 - 400 = 41.888^2 - 400 = 1354.6045$$

$\Rightarrow \quad \omega_2 = 36.805$ rad/s

$$\therefore \quad N_2 = \frac{60\omega_2}{2\pi} = \frac{36.805 \times 60}{2\pi}$$

$= 351.46$ rpm ~ 352 rpm Choice(C)

57.



The loading is equivalent to a combination of downward and upward loadings as shown in figure.
So deflection at the free end

$$y = \frac{wL^4}{8EI} - \left[\frac{wa^4}{8EI} + \frac{wa^3}{6EI} \times a\right]$$

where $L = 2a$ and EI = flexural rigidity

$$\therefore \quad y = \frac{w}{EI}\left[\frac{L^4}{8} - \left(\frac{a^4}{8} + \frac{a^4}{6}\right)\right]$$

$$= \frac{1 \times 10^3}{5 \times 10^6}\left[\frac{2^4}{8} - \left(\frac{1}{8} + \frac{1}{6}\right)\right]$$

$$= \frac{1}{5 \times 10^3}\left[2 - \left(\frac{1}{8} + \frac{1}{6}\right)\right]$$

$= 0.3417 \times 10^{-3}$ m
$= 0.3417$ mm Answer 0.33 to 0.35

58. Maximum size of the pin = 20 + 0.025 = 20.025 mm
Maximum plate thickness = 20 + 2
= 22 micron = 0.022 mm
Size of the GO gauge = Maximum size of the plated pin
= 20.025 + 2(0.022) = 20.069 mm Choice (B)

59. k_2 and k_3 are in series $\rightarrow k_s = \frac{k_2k_3}{k_2 + k_3}$

$$= \frac{2 \times 3}{(2+3)} = 1.2 \text{ kN/m}$$

k_s and k_1 are in parallel
$\Rightarrow \quad k_{eff} = k_s + k_1 = 1.2 + 1$
$= 2.2$ kN/m $= 2200$ N/m
m = 2 kg

$$\therefore \quad \omega = \sqrt{\frac{k_{eff}}{m}} = \sqrt{\frac{2200}{2}} = 33.17 \text{ rad/s}$$ Choice(D)

60. $\delta = \frac{WL^3}{48EI}$ (for simply supported beam with concentrated load at centre)

$$\therefore \quad k = \frac{48EI}{L^3}$$

$$I = \frac{\pi}{64}d^4 = \frac{\pi}{64}\times(0.03)^4 = 3.9761\times10^{-8}\,m^4$$

$$\therefore\quad k = \frac{48\times2.1\times10^{11}\times3.9761\times10^{-8}}{(0.4)^3}$$

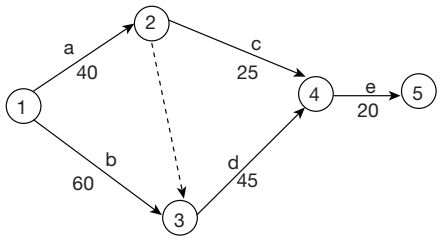
$$= 6262357.5\ N/m$$

$$\therefore\quad \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{6262357.5}{15}} = 646.135\ rad/s$$

$$\therefore\quad f = \frac{\omega}{2\pi} = \frac{646.135}{2\pi} = 102.836\ Hz$$

Answer 102.800 to 103.850

61.



Paths	Durations
a- c – e	40 + 25 + 20 = 85
a- d – e	40 + 45 + 20 = 105
b – d- e	60 + 45 + 20 = 125

So critical path is *b – d – e* with duration 125 days

Critical activities	Standard deviation (σ)	Variance (σ^2)
b d	9	81
e	6	36
	3	9

Variance of critical path $(Var)_{cp}$ = 81 + 36 + 9 = 126

Standard deviation of critical path

$\sigma_{cp} = \sqrt{(Var)_{cp}}$

$= \sqrt{126} = 11.225$ days Choice (A)

62. $\dot{Q} = \dot{m}_h c_{p_h}\left(T_{h_i} - T_{h_e}\right) = \dot{m}_c c_{p_c}\left(T_{c_e} - T_{c_i}\right)$

Given $2\dot{m}_h = \dot{m}_c$ *and* $c_{p_h} = 2c_{p_c}$

$$\Rightarrow\quad \left(T_{h_i} - T_{h_e}\right) = \left(T_{c_e} - T_{c_i}\right)$$

i.e., $\left(T_{h_i} - T_{c_e}\right) = \left(T_{h_e} - T_{c_i}\right)$

i.e., $\theta_1 = \theta_2 \Rightarrow \theta_1 = \theta_2 = LMTD = 26°C$

$$\therefore\quad T_{c_e} = T_{h_i} - LMTD = 100 - 26 = 74°C$$

$$T_{h_e} = T_{c_i} + LMTD$$

$$= 20 + 26 = 46°C$$

$$\therefore\quad \frac{T_{c_e}}{T_{h_e}} = \frac{74}{46} = 1.6087 = 1.61$$ Choice(A)

63. Reynolds number at *x*

$$R_{e_x} = \frac{Ux}{\nu}$$

Where ν = kinematic viscosity

At *x* = 1,

$$R_{e_x} = \frac{2\times1}{1.6\times10^{-5}} = 1.25\times10^5$$

$$\delta = \frac{5.48\times1}{\sqrt{1.25\times10^5}} = 0.0155\ m$$

$$\frac{du}{dy} = U\left[\frac{2}{\delta} - \frac{2y}{\delta^2}\right]$$

$$\left|\frac{du}{dy}\right|_{y=0} = \frac{2U}{\delta}$$

Wall shear stress $\tau_0 = \mu\left|\frac{du}{dy}\right|_{y=0}$

$$= \mu\times\frac{2U}{\delta} = \frac{\nu\rho\times2U}{\delta}$$

$$= \frac{1.6\times10^{-5}\times1.25\times2\times2}{0.0155} = 5.16\times10^{-3}\ N/m^2$$

Answer 5.15 to 5.18

64. $\Psi = x^2 - y^2$

$$\frac{\partial\psi}{\partial y} = -u$$

$$\frac{\partial\psi}{\partial x} = v$$

$\Rightarrow$ $2x = v$ and $2y = u$

$\therefore$ Velocity $\vec{V} = ui + vj = 2yi + 2xj$

At *x* = (1, 2)

$\vec{V} = (2\times2)i + (2\times1)j = 4i + 2j$

Magnitude of velocity $|V| = \sqrt{4^2 + 2^2}$

$= \sqrt{20} = 4.472$ Answer 4.46 to 4.48

65. Let α, β and ϕ be rake angle, angle of chip friction and shear plane angle respectively.

According to Merchants theory, 2ϕ + β – α = 90°

α = 15°

Chip thickness ratio (cutting ratio) *r* = 0.714

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

$$= \frac{0.714\cos15°}{1 - 0.714\sin15°} = 0.8460$$

$\Rightarrow$ ϕ = 40.23°

$\therefore$ β = 90 + α – 2ϕ

= 90 + 15 – 2 × 40.23

= 24.54°

Coefficient of friction μ = tanβ

= tan24.54° = 0.4566 Answer 0.45 to 0.46.