

GATE : 2008

ME : Mechanical Engineering

Duration : Three Hours

Maximum Marks : 150

Read the following instructions carefully

1. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.
2. All the questions in this question paper are of objective type.
3. Questions must be answered on Objective Response Sheet (ORS) by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the ORS. **Each question has only one correct answer.** In case you wish to change an answer, erase the old answer completely. More than one answer bubbled against a question will be treated as a wrong answer.
4. Questions 1 through 20 are 1-mark questions and questions 21 through 85 are 2-mark questions.
5. Questions 71 through 73 is one set of common data questions, questions 74 and 75 is another pair of common data questions. The question pairs (76, 77), (78, 79), (80, 81), (82, 83) and (84, 85) are questions with linked answers. The answer to the second question of the above pairs will depend on the answer to the first question of the pair. If the first question in the linked pair is wrongly answered or is un-attempted, then the answer to the second question in the pair will not be evaluated.
6. Un-attempted questions will carry zero marks.
7. **NEGATIVE MARKING:** For Q.1 to Q.20, 0.25 mark will be deducted for each wrong answer. For Q.21 to Q.75, 0.5 mark will be deducted for each wrong answer. For the pairs of questions with linked answers, there will be negative marks only for wrong answer to the first question, i.e; for Q.76, Q.78, Q.80, Q.82 and Q.84, 0.5 mark will be deducted for each wrong answer. There is no negative marking for Q.77, Q.79, Q.81, Q.83 and Q.85.
8. Calculator **without data connectivity** is allowed in the examination hall.
9. Charts, graph sheets and tables are NOT allowed in the examination hall.
10. Rough work can be done on the question paper itself. Additional blank pages are given at the end of the question paper for rough work.

Q.1 - Q.20 carry one mark each.

1. In the Taylor series expansion of e^x about $x = 2$, the coefficient of $(x - 2)^4$ is

- (a) $\frac{1}{4!}$ (b) $\frac{2^4}{4!}$
 (c) $\frac{e^2}{4!}$ (d) $\frac{e^4}{4!}$

2. Given that $\ddot{x} + 3x = 0$, and $x(0) = 1$, $\dot{x}(0) = 0$, what is $x(1)$?
 (a) -0.99 (b) -0.16
 (c) 0.16 (d) 0.99

3. The value of $\lim_{x \rightarrow 8} \frac{x^{1/3} - 2}{(x - 8)}$ is

- (a) $\frac{1}{16}$ (b) $\frac{1}{12}$
 (c) $\frac{1}{8}$ (d) $\frac{1}{4}$

4. A coin is tossed 4 times. What is the probability of getting heads exactly 3 times?

- (a) $\frac{1}{4}$ (b) $\frac{3}{8}$
 (c) $\frac{1}{2}$ (d) $\frac{3}{4}$

5. The matrix $\begin{bmatrix} 1 & 2 & 4 \\ 3 & 0 & 6 \\ 1 & 1 & p \end{bmatrix}$ has one eigenvalue equal to 3. The sum of the other two eigenvalues is

- (a) p (b) $p - 1$
 (c) $p - 2$ (d) $p - 3$

6. The divergence of the vector field $(x - y) \hat{i} + (y - x) \hat{j} + (x + y + z) \hat{k}$ is

- (a) 0 (b) 1
 (c) 2 (d) 3

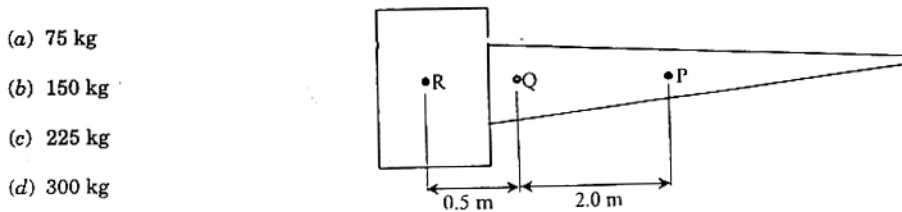
7. The transverse shear stress acting in a beam of rectangular cross-section, subjected to a transverse shear load, is

- (a) variable with maximum at the bottom of the beam
 (b) variable with maximum at the top of the beam
 (c) uniform
 (d) variable with maximum of the neutral axis

8. A rod of length L and diameter D is subjected to a tensile load P . Which of the following is sufficient to calculate the resulting change in diameter?
- (a) Young's modulus
(b) Shear modulus
(c) Poisson's ratio
(d) Both Young's modulus and shear modulus

9. A straight rod of length $L(t)$, hinged at one end and freely extensible at the other end, rotates through an angle $\theta(t)$ about the hinge. At time t , $L(t) = 1$ m, $\dot{L}(t) = 1$ m/s, $\theta(t) = \frac{\pi}{4}$ rad and $\dot{\theta}(t) = 1$ rad/s. The magnitude of the velocity at the other end of the rod is
- (a) 1 m/s
(b) $\sqrt{2}$ m/s
(c) $\sqrt{3}$ m/s
(d) 2 m/s

10. A cantilever type gate hinged at Q is shown in the figure. P and R are the centers of gravity of the cantilever part and the counterweight respectively. The mass of the cantilever part is 75 kg. The mass of the counterweight, for static balance, is



- (a) 75 kg
(b) 150 kg
(c) 225 kg
(d) 300 kg

11. A planar mechanism has 8 links and 10 rotary joints. The number of degrees of freedom of the mechanism, using Gruebler's criterion, is
- (a) 0
(b) 1
(c) 2
(d) 3

12. An axial residual compressive stress due to a manufacturing process is present on the outer surface of a rotating shaft subjected to bending. Under a given bending load, the fatigue life of the shaft in the presence of the residual compressive stress is
- (a) decreased
(b) increased or decreased, depending on the external bending load
(c) neither decreased nor increased
(d) increased

13. 2 moles of oxygen are mixed adiabatically with another 2 moles of oxygen in mixing chamber, so that the final total pressure and temperature of the mixture become same as those of the individual constituents at their initial states. The universal gas constant is given as R . The change in entropy due to mixing, per mole of oxygen, is given by
- (a) $-R \ln 2$
(b) 0
(c) $R \ln 2$
(d) $R \ln 4$

14. For flow of fluid over a heated plate, the following fluid properties are known
viscosity = 0.001 Pa.s ; specific heat at constant pressure = 1 kJ/kg.K ;
thermal conductivity = 1 W/m.k.

The hydrodynamic boundary layer thickness at a specified location on the plate is 1 mm. The thermal boundary layer thickness at the same location is

- (a) 0.001 mm
(b) 0.01 mm
(c) 1 mm
(d) 1000 mm

15. For the continuity equation given by $\vec{\nabla} \cdot \vec{V} = 0$ to be valid, where \vec{V} is the velocity vector, which one of the following is a necessary condition?

- (a) steady flow
(b) irrotational flow
(c) inviscid flow
(d) incompressible flow

16. Which one of the following is NOT a necessary assumption for the air-standard Otto cycle?

- (a) All processes are both internally as well as externally reversible.
(b) Intake and exhaust processes are constant volume heat rejection processes.
(c) The combustion process is a constant volume heat addition process.
(d) The working fluid is an ideal gas with constant specific heats.

17. In an M/M/1 queuing system, the number of arrivals in an interval of length T is a Poisson random

variable (i.e. the probability of there being n arrivals in an interval of length T is $\frac{e^{-\lambda T} (\lambda T)^n}{n!}$).

The probability density function f(t) of the inter-arrival time is given by

(a) $\lambda^2 \left(e^{-\lambda^2 t} \right)$
(b) $\frac{e^{-\lambda^2 t}}{\lambda^2}$

(c) $\lambda e^{-\lambda t}$
(d) $\frac{e^{-\lambda t}}{\lambda}$

18. A set of 5 jobs is to be processed on a single machine. The processing time (in days) is given in the table below. The holding cost for each job is Rs. K per day.

Job	Processing time
P	5
Q	2
R	3
S	2
T	1

A schedule that minimizes the total inventory cost is

- (a) T-S-Q-R-P
(b) P-R-S-Q-T
(c) T-R-S-Q-P
(d) P-Q-R-S-T

19. For generating a Coon's surface we require

- (a) a set of grid points on the surface
(b) a set of grid control points
(c) four bounding curves defining the surface
(d) two bounding curves and a set of grid control points

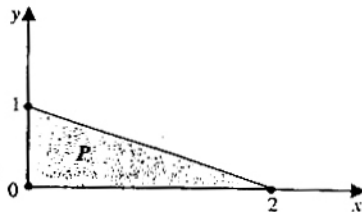
20. Internal gear cutting operation can be performed by

- (a) milling
(b) shaping with rack cutter
(c) shaping with pinion cutter
(d) hobbing

Q.21 to Q.75 carry two marks each.

21. Consider the shaded triangular region P shown in the figure. What is $\iint_P xy \, dx \, dy$?

- (a) $\frac{1}{6}$
 (b) $\frac{2}{9}$
 (c) $\frac{1}{16}$
 (d) 1



22. The directional derivative of the scalar function $f(x, y, z) = x^2 + 2y^2 + z$ at the point $P = (1, 1, 2)$ in the direction of the vector $\vec{a} = 3\hat{i} - 4\hat{j}$ is

- (a) -4
 (b) -2
 (c) -1
 (d) 1

23. For what value of a, if any, will the following system of equations in x, y and z have a solution?

$$\begin{aligned} 2x + 3y &= 4 \\ x + y + z &= 4 \\ x + 2y - z &= a \end{aligned}$$

- (a) Any real number
 (b) 0
 (c) 1
 (d) There is no such value

24. Which of the following integrals is unbounded?

(a) $\int_0^{\frac{\pi}{4}} \tan x \, dx$

(b) $\int_0^{\infty} \frac{1}{x^2 + 1} \, dx$

(c) $\int_0^{\infty} xe^{-x} \, dx$

(d) $\int_0^1 \frac{1}{1-x} \, dx$

25. The integral $\oint f(z) \, dz$ evaluated around the unit circle on the complex plane for $f(z) = \frac{\cos z}{z}$ is

- (a) $2\pi i$
 (b) $4\pi i$
 (c) $-2\pi i$
 (d) 0

26. The length of the curve $y = \frac{2}{3}x^{3/2}$ between $x = 0$ and $x = 1$ is

- (a) 0.27
 (b) 0.67
 (c) 1
 (d) 1.22

27. The eigenvectors of the matrix $\begin{bmatrix} 1 & 2 \\ 0 & 2 \end{bmatrix}$ are written in the form $\begin{bmatrix} 1 \\ a \end{bmatrix}$ and $\begin{bmatrix} 1 \\ b \end{bmatrix}$. What is $a + b$?

- (a) 0
 (b) $\frac{1}{2}$
 (c) 1
 (d) 2

28. Let $f = y^x$. What is $\frac{\partial^2 f}{\partial x \partial y}$ at $x = 2, y = 1$?

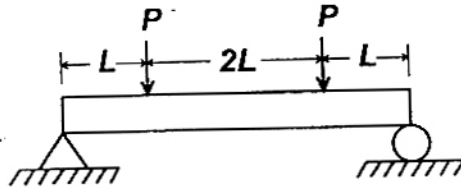
- (a) 0
 (b) $\ln 2$
 (c) 1
 (d) $\frac{1}{\ln 2}$

29. It is given that $y'' + 2y' + y = 0, y(0) = 0, y(1) = 0$. What is $y(0.5)$?

- (a) 0
 (b) 0.37
 (c) 0.62
 (d) 1.13

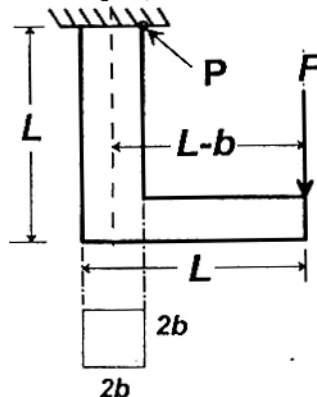
30. The strain energy stored in the beam with flexural rigidity FL and loaded as shown in the figure is

- (a) $\frac{P^2 L^3}{3EI}$
 (b) $\frac{2P^2 L^3}{3EI}$
 (c) $\frac{4P^2 L^3}{3EI}$
 (d) $\frac{8P^2 L^3}{3EI}$



31. For the component loaded with a force F as shown in the figure, the axial stress at the corner point P is

- (a) $\frac{F(3L - b)}{4b^3}$
 (b) $\frac{F(3L + b)}{4b^3}$
 (c) $\frac{F(3L + 4b)}{4b^3}$
 (d) $\frac{F(3L + 2b)}{4b^3}$

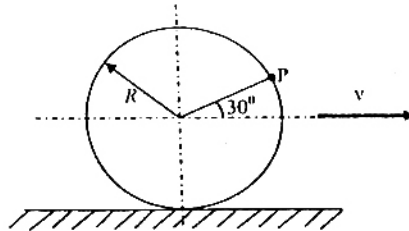


32. A solid circular shaft of diameter 100 mm is subjected to an axial stress of 50 MPa. It is further subjected to a torque of 10 kNm. The maximum principal stress experienced on the shaft is closest to

- (a) 41 MPa
(b) 82 MPa
(c) 164 MPa
(d) 204 MPa

33. A circular disk of radius R rolls without slipping at a velocity v . The magnitude of the velocity at point P (see figure) is

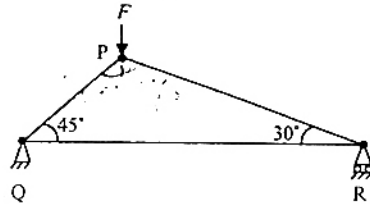
- (a) $\sqrt{3} v$
(b) $\sqrt{3} v/2$
(c) $v/2$
(d) $2v/\sqrt{3}$



34. Consider a truss PQR loaded at P with a force F as shown in the figure.

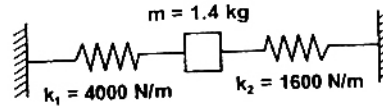
The tension in the member QR is

- (a) $0.5 F$
(b) $0.63 F$
(c) $0.73 F$
(d) $0.87 F$



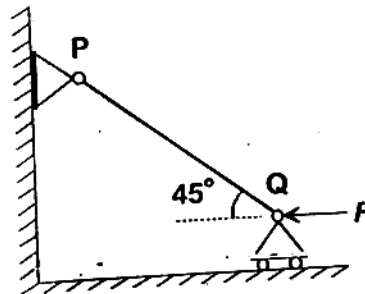
35. The natural frequency of the spring mass system shown in the figure is closest to

- (a) 8 Hz
(b) 10 Hz
(c) 12 Hz
(d) 14 Hz



36. The rod PQ of length L and with flexural rigidity EI is hinged at both ends. For what minimum force F is it expected to buckle?

- (a) $\frac{\pi^2 EI}{L^2}$
(b) $\frac{\sqrt{2}\pi^2 EI}{L^2}$
(c) $\frac{\pi^2 EI}{\sqrt{2}L^2}$
(d) $\frac{\pi^2 EI}{2L^2}$



37. In a cam design, the rise motion is given by a simple harmonic motion (SHM) $s = \frac{h}{2} \left(1 - \cos \frac{\pi\theta}{\beta} \right)$ where h is total rise, θ is camshaft angle, β is the total angle of the rise interval. The jerk is given by

(a) $\frac{h}{2} \left(1 - \cos \frac{\pi\theta}{\beta} \right)$

(b) $\frac{\pi h}{\beta} \sin \left(\frac{\pi\theta}{\beta} \right)$

(c) $\frac{\pi^2 h}{\beta^2} \cos \left(\frac{\pi\theta}{\beta} \right)$

(d) $-\frac{\pi^3 h}{\beta^3} \sin \left(\frac{\pi\theta}{\beta} \right)$

38. A uniform rigid rod of mass $m = 1$ kg and length $L = 1$ m is hinged at its centre and laterally supported at one end by a spring of spring constant $k = 300$ N/m. The natural frequency ω_n in rad/s is

(a) 10

(b) 20

(c) 30

(d) 40

39. A compression spring is made of music wire of 2 mm diameter having a shear strength and shear modulus of 800 MPa and 80 GPa respectively. The mean coil diameter is 20 mm, free length is 40 mm and the number of active coils is 10. If the mean coil diameter is reduced to 10 mm, the stiffness of the spring is approximately

(a) decreased by 8 times

(b) decreased by 2 times

(c) increased by 2 times

(d) increased by 8 times

40. A journal bearing has shaft diameter of 40 mm and a length of 40 mm. The shaft is rotating at 20 rad/s and the viscosity of the lubricant is 20 mPa.s. The clearance is 0.020 mm. The loss of torque due to the viscosity of the lubricant is approximately

(a) 0.040 Nm

(b) 0.252 Nm

(c) 0.400 Nm

(d) 0.652 Nm

41. A clutch has outer and inner diameters 100 mm and 40 mm respectively. Assuming a uniform pressure of 2 MPa and coefficient of friction of liner material 0.4, the torque carrying capacity of the clutch is

(a) 148 Nm

(b) 196 Nm

(c) 372 Nm

(d) 490 Nm

42. A spur gear has a module of 3 mm, number of teeth 16, a face width of 36 mm and a pressure angle of 20°. It is transmitting a power of 3 kW at 20 rev/s. Taking a velocity factor of 1.5, and a form factor of 0.3, the stress in the gear tooth is about

(a) 32 MPa

(b) 46 MPa

(c) 58 MPa

(d) 70 MPa

43. Match the type of gears with their most appropriate description.

Type of gear	Description
P Helical	1 Axes non parallel and non intersectin
Q Spiral Bevel	2 Axes parallel and teeth are inclined to the axis
R Hypoid	3 Axes parallel and teeth are parallel to the axis
S Rack and pinion	4 Axes are perpendicular and intersecting, and teeth are inclined to the axis
	5 Axes are perpendicular and used for large speed reduction
	6 Axes parallel and one of the gears has infinite radius

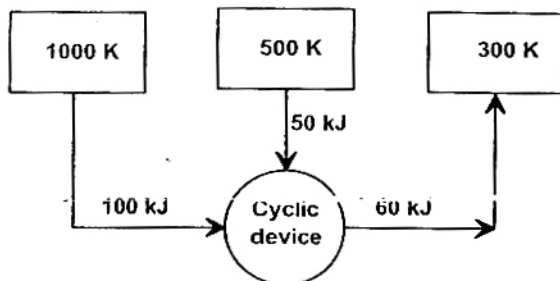
(a) P-2, Q-4, R-1, S-6

(b) P-1, Q-4, R-5, S-6

(c) P-2, Q-6, R-4, S-2

(d) P-6, Q-3, R-1, S-5

44. A gas expands in a frictionless piston-cylinder arrangement. The expansion process is very slow, and is resisted by an ambient pressure of 100 kPa. During the expansion process, the pressure of the system (gas) remains constant at 300 kPa. The change in volume of the gas is 0.01 m^3 . The maximum amount of work that could be utilized from the above process is
- (a) 0 kJ (b) 1 kJ
(c) 2 kJ (d) 3 kJ
45. The logarithmic mean temperature difference (LMTD) of a counterflow heat exchanger is 20°C . The cold fluid enters at 20°C and the hot fluid enters at 100°C . Mass flow rate of the cold fluid is twice that of the hot fluid. Specific heat at constant pressure of the hot fluid is twice that of the cold fluid. The exit temperature of the cold fluid
- (a) is 40°C (b) is 60°C
(c) is 80°C (d) cannot be determined
46. A two dimensional fluid element rotates like a rigid body. At a point within the element, the pressure is 1 unit. Radius of the Mohr's circle, characterizing the state of stress at that point, is
- (a) 0.5 unit (b) 0 unit
(c) 1 unit (d) 2 unit
47. A cyclic device operates between three thermal reservoirs, as shown in the figure. Heat is transferred to/from the cyclic device. It is assumed that heat transfer between each thermal reservoir and the cyclic device takes place across negligible temperature difference. Interactions between the cyclic device and the respective thermal reservoirs that are shown in the figure are all in the form of heat transfer.

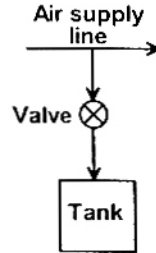


The cyclic device can be

- (a) a reversible heat engine
(b) a reversible heat pump or a reversible refrigerator
(c) an irreversible heat engine
(d) an irreversible heat pump or an irreversible refrigerator
48. A balloon containing an ideal gas is initially kept in an evacuated and insulated room. The balloon ruptures and the gas fills up the entire room. Which one of the following statements is TRUE at the end of above process?
- (a) The internal energy of the gas decreases from its initial value, but the enthalpy remains constant
(b) The internal energy of the gas increases from its initial value, but the enthalpy remains constant
(c) Both internal energy and enthalpy of the gas remain constant
(d) Both internal energy and enthalpy of the gas increase

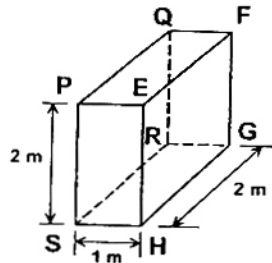
49. A rigid, insulated tank is initially evacuated. The tank is connected with a supply line through which air (assumed to be ideal gas with constant specific heats) passes at 1 MPa, 350°C. A valve connected with the supply line is opened and the tank is charged with air until the final pressure inside the tank reaches 1 MPa. The final temperature inside the tank

- (a) is greater than 350°C
 (b) is less than 350°C
 (c) is equal to 350°C
 (d) may be greater than, less than, or equal to 350°C, depending on the volume of the tank



50. For the three-dimensional object shown in the figure below, five faces are insulated. The sixth face (PQRS), which is not insulated, interacts thermally with the ambient, with a convective heat transfer coefficient of 10 W/m².K. The ambient temperature is 30°C. Heat is uniformly generated inside the object at the rate of 100 W/m³. Assuming the face PQRS to be at uniform temperature, its steady state temperature is

- (a) 10°C
 (b) 20°C
 (c) 30°C
 (d) 40°C



51. Water, having a density of 1000 kg/m³, issues from a nozzle with a velocity of 10 m/s and the jet strikes a bucket mounted on a Pelton wheel. The wheel rotates at 10 rad/s. The mean diameter of the wheel is 1 m. The jet is split into two equal streams by the bucket, such that each stream is deflected by 120°, as shown in the figure. Friction in the bucket may be neglected. Magnitude of the torque exerted by the water on the wheel, per unit mass flow rate of the incoming jet, is

- (a) 0 (N.m)/(kg/s)
 (b) 1.25 (N.m)/(kg/s)
 (c) 2.5 (N.m)/(kg/s)
 (d) 3.75 (N.m)/(kg/s)

