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Preface

B. Singh (Ex. IES)

When in fifteenth century, some audacious mariners had sailed to discover America; in the eyes of their contemporaries it wasn't justifiable but the fervour to uncover America from rest of the world made them to set the voyage. As it is rightly said "Heritage of man is not the earth but the entire universe"; and now man dares to assault the sky, just because of thinking what was never thought

To help all aspirants looking forward to be the part of INDIA's next space exploration MADE EASY team has solved accurately and in detail all previous years' papers of DRDO and ISRO.

MADE EASY team has made deep study of previous exam papers and observed that a good percentage of questions are repetitive. This book containing fully explained questions from 2006 onwards will serve as an effective tool to succeed in examination.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand upto the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes

B. Singh

CMD, MADE EASY Group

DRDO and ISRO
Mechanical Engineering & RAC

Previous Years Solved Papers

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ME

DRDO

Defence Research and Development Organisation

(Technical & Non-Technical Sections)

- 2008 (Objective)
- 2009 (Objective)
- 2019 (Conventional)

Previous Solved Papers

1

DRDO 2008 : ME

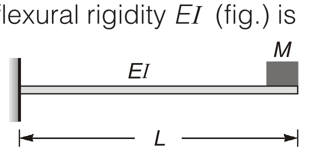
(Defence Research and Development Organisation)

SECTION-A (TECHNICAL)

Q.1 In the case of a curved beam subjected to pure bending, which of the following is true?
(a) Neutral axis coincides with the centroidal axis.
(b) Neutral axis lies between the centroidal axis and the center of curvature.
(c) Location of neutral axis depends upon the magnitude of bending moment.
(d) There is no neutral axis.

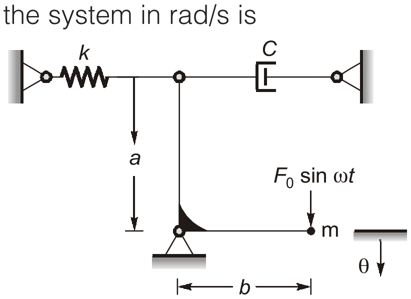
Q.2 A 10 m radius thin spherical tank is to be used to store gas. If the wall thickness of the tank is 10 mm and the allowable tensile stress for the material of the tank is 125 MPa, the maximum possible gas pressure (neglecting radial stress) is
(a) 0.25 MPa (b) 0.125 MPa
(c) 0.5 MPa (d) 1 MPa

Q.3 Natural frequency (rad/s) of mass *M* on the free end of a cantilever beam of negligible mass length *L* and flexural rigidity EI (fig.) is



(a) $\sqrt{\frac{EI}{3ML^3}}$ (b) $\frac{1}{3}\sqrt{\frac{EI}{ML^3}}$
(c) $\sqrt{\frac{3EI}{ML^3}}$ (d) $\sqrt[3]{\frac{EI}{ML^3}}$

Q.4 For the system shown in figure, the angular displacement θ, the undamped natural frequency of the system in rad/s is

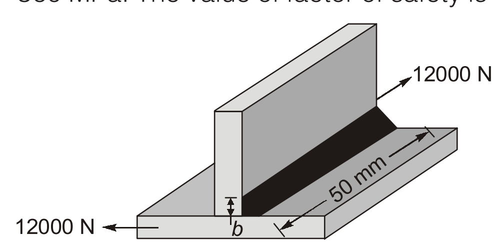


(a) $\frac{a}{b}\sqrt{\frac{k}{m}}$ (b) $\frac{b}{a}\sqrt{\frac{k}{m}}$
(c) $\sqrt{\frac{ak}{bm}}$ (d) $\sqrt{\frac{bk}{am}}$

Q.5 For a one degree of freedom system described by the differential equation $10\ddot{x} + 200\dot{x} + 810x = 0$ (units as per SI system), which of the following is true?
(a) The system is under damped
(b) The system is over damped
(c) The system is critically damped
(d) The system has no damping

Q.6 Spur gears are used for
(a) connecting two intersecting shafts
(b) transmitting power between two intersecting shafts
(c) transmitting power between two parallel shafts
(d) transmitting power between inline shafts

Q.7 A 6 mm fillet weld is 50 mm long and carries a steady load of 12000 N along the weld as shown in figure. The weld metal has yield strength of 360 MPa. The value of factor of safety is



(a) 1.59 (b) 3.18
(c) 4.18 (d) 6.36

Q.8 Which of the following bearings are termed as anti friction bearings?
(a) Journal bearings
(b) Gas lubricated bearings
(c) Ball and roller bearings
(d) Air bearings

Q.9 In a slider-crank mechanism, the crank is rotating with an angular velocity of 20 rad/s in counterclockwise direction. At the instant when the crank is perpendicular to the direction of the piston movement, velocity of the piston is 2 m/s. Radius of the crank is

(a) 100 cm (b) 10 cm
(c) 1 cm (d) 0.1 cm

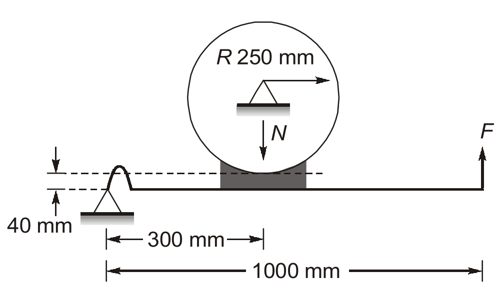
Q.10 Two parallel shafts whose axes are separated by a distance of 75 mm are to be connected by a spur gear set so that the output shaft rotates at 50% of the speed of the input shaft. Which of the following could be the possible pitch circle diameters of the gears?

(a) 25 mm and 50 mm
(b) 30 mm and 60 mm
(c) 50 mm and 100 mm
(d) 60 mm and 120 mm

Q.11 A square key is used to key a gear to a 40 mm diameter shaft. The hub length of the gear is 50 mm. Both shaft and the key are made of same material having allowable shear strength of 50 MPa. If a torque of 500 Nm is to be transmitted, what is the minimum value of the dimension of the sides of the square key?

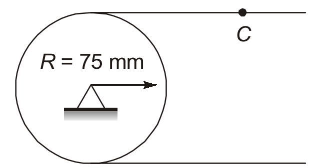
(a) 20 mm (b) 10 mm
(c) 5 mm (d) 1 mm

Q.12 A 250 mm radius brake drum contacts a single shoe as shown in figure and sustains a torque of 300 Nm at 500 rpm. Coefficient of friction is 0.3. Force *F* required for braking in the case of counterclockwise rotation of the brake drum is



(a) 1152 N (b) 1248 N
(c) 4000 N (d) 2000 N

Q.13 The motion of pulley (Figure) is controlled by cable *C* which has a constant acceleration of 0.225 m/s^2. The magnitude of angular acceleration of the pulley is



(a) 3 rad/s^2 (b) 4 rad/s^2
(c) 225 rad/s^2 (d) 6 rad/s^2

Q.14 Which of the following is a flexible coupling?

(a) Muff coupling
(b) Marine coupling
(c) Protected type flange coupling
(d) Oldham coupling

Q.15 Two concentric helical springs with spring constants 200 N/mm and 160 N/mm when subjected to a load of 1800 N will deflect by

(a) 5 mm (b) 10 mm
(c) 20.25 mm (d) 40.5 mm

Q.16 Tearing efficiency of a double riveted lap joint having a pitch of 60 mm and rivet hole diameter of 18 mm is

(a) 30% (b) 35%
(c) 60% (d) 70%

Q.17 For a fly wheel operating between maximum and minimum speeds of ω_1 and ω_2 respectively, coefficient of fluctuation of speed is

(a) $\omega_2 - \omega_2$ (b) $\frac{2(\omega_1 - \omega_2)}{\omega_1 + \omega_2}$

(c) $\frac{\omega_1 - \omega_2}{2(\omega_1 + \omega_2)}$ (d) $\frac{\omega_1 - \omega_2}{\omega_1}$

Q.18 A 20 kg car moving at a speed of 20 m/s to the right collides with a 35 kg car which is at rest. After the collision the 35 kg car is moving towards right at a speed of 10 m/s. The speed of the 20 kg car is

(a) 2.5 m/s (b) –2.5 m/s
(c) 50 m/s (d) 0

Q.19 Endurance limit of a component

(a) increases as the surface roughness increases
(b) decreases as the surface roughness increases
(c) initially increases with the increase in surface roughness and then decreases
(d) does not depend upon the surface roughness

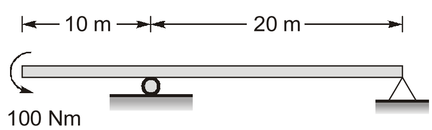
Q.20 A thin cylindrical pressure vessel with mean diameter 10 m and wall thickness 20 mm is subjected to an internal fluid pressure of 0.4 MPa. If the yield strength of the material of the cylinder is 200 MPa, the factor of safety according to maximum shear stress theory (neglecting radial stress) is

(a) 0.5 (b) 1
(c) 1.5 (d) 2

Q.21 A discontinuity or jump in the shear force diagram occurs whenever a beam is loaded by

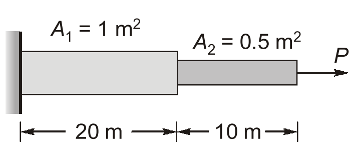
(a) a distributed moment
(b) a distributed force
(c) a concentrated moment
(d) a concentrated force

Q.22 For the beam loaded as shown in figure the magnitude of bending moment at the roller support is



(a) 100 Nm (b) 1000 Nm
(c) 0 (d) 2000 Nm

Q.23 A rod of variable cross-section (areas A_1 and A_2) fixed at one end is subjected to an axial force P as shown in figure. If the allowable normal stress in tension is 100 MPa then the maximum allowable load *P* (neglecting stress concentration) is



(a) 100 MN (b) 200 MN
(c) 50 MN (d) 50 N

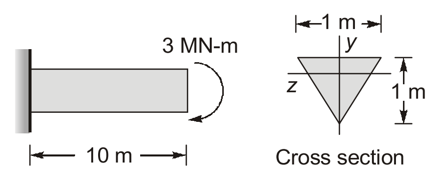
Q.24 When a solid circular shaft is in pure torsion and deforms elastically, the shearing stress in the shaft

(a) is inversely proportional to the shear modulus of elasticity
(b) varies linearly with the radial distance from the axis of the shaft
(c) varies linearly with length of the shaft
(d) is inversely proportional to the diameter of the shaft

Q.25 At a point in a body the normal stresses are $\sigma_x = \sigma$ and $\sigma_y = \sigma$. *E* is the Young's modulus and ν is the Poisson's ratio of the material of the body. Assuming the material to be linearly elastic and isotropic, for plane stress condition the ratio of σ_x to $\in_x$ is

(a) $\frac{E}{1-\nu}$ (b) E
(c) $\frac{E}{\nu}$ (d) $\frac{E}{1+\nu}$

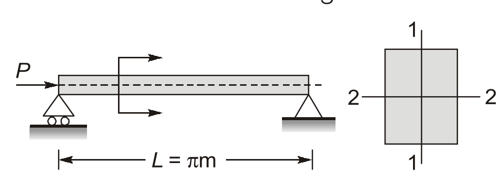
Q.26 A cantilever beam has the cross-section of an isosceles triangle and is loaded as shown in figure. If the moment of inertia of the cross-section $I_{zz} = \frac{1}{36}$ m^4, then the maximum tensile bending stress is



Cross section

(a) 1/16 MPa (b) 72 MPa
(c) 36 MPa (d) 1/36 MPa

Q.27 A long slender column is pin-supported at the ends and compressed by an axial load *P* as shown in figure. If I_{11} = 100 cm^4, I_{22} = 200 cm^4 and Young's modulus of elasticity = 100 GPa, then the critical load for buckling is



(a) 500 kN (b) 200 kN
(c) 100 kN (d) 1000 GN

Q.28 The linear relation between the stress and strain of a material is valid until

(a) fracture stress (b) elastic limit
(c) ultimate stress (d) proportional limit

Q.29 Which of the following can be the measure of ductility of a material?

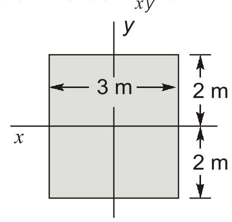
(a) Area under engineering stress-strain curve
(b) Percent reduction in area in tension test
(c) Yield stress
(d) Ultimate stress

Q.30 At the point of contraflexure of a beam
(a) the shear force is zero
(b) sign of curvature in the deflection curve changes
(c) the bending moment reaches maximum value
(d) maximum deflection occurs

Q.31 A material has a Poisson's ratio of 0.5. If a body is made of this material and subjected to external forces (within the elastic limit) then the final volume of the body is
(a) thrice that of the initial volume of the body
(b) twice that of the initial volume of the body
(c) zero
(d) equal to the initial volume of the body

Q.32 If at a point in a body σ_x = 70 MPa, σ_y = 60 MPa and τ_{xy} = –5 MPa then the radius of the Mohr's circle is equal to
(a) $5\sqrt{5}$ MPa (b) $2\sqrt{5}$ MPa
(c) $5\sqrt{2}$ MPa (d) 25 MPa

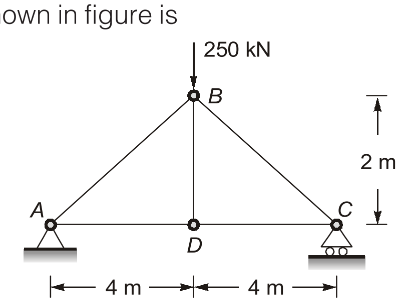
Q.33 A rectangular area is shown in figure. The value of product of inertial I_{xy} is



(a) 12 m^4 (b) 16 m^4
(c) 9 m^4 (d) 0

Q.34 Hinge support is not capable of resisting
(a) horizontal force
(b) moment
(c) vertical force
(d) both horizontal and vertical forces

Q.35 The axial force in the member *BD* of a steel truss shown in figure is



(a) 250 kN (b) –250 kN
(c) 0 (d) 125 kN

Q.36 The motion of a particle is defined by the relation $x = \frac{5}{2}t^2 - 20t + 10$, where x and t are expressed in meters and seconds respectively. The position x of the particle at zero velocity is
(a) 30 m (b) –30 m
(c) –20 m (d) 50 m

Q.37 For any process, the second law of thermodynamics requires that the entropy change of the system be
(a) positive or zero
(b) zero
(c) negative or zero
(d) positive zero or negative, but does not say which

Q.38 A system is changed from a single initial equilibrium state to the same final equilibrium state by two different processes, one reversible and the other irreversible. Which of the following is true, where ΔS refer to the change in entropy of the system?
(a) $\Delta S_{irr} = \Delta S_{rev}$
(b) $\Delta S_{irr} > \Delta S_{rev}$
(c) $\Delta S_{irr} < \Delta S_{rev}$
(d) either (b) or (c) depending on the nature of the process

Q.39 An inventor claims to have devised an engine that produces 2000 kJ of work while receiving 1900 kJ of heat from a single reservoir during a complete cycle of the engine. Such an engine would violate
(a) only the first law of thermodynamics and no other laws.
(b) only the second law of thermodynamics and no other laws.
(c) both the first and the second laws of thermodynamics.
(d) neither the first nor the second laws of thermodynamics.

Q.40 The COP of a Carnot heat pump operating between –3°C and 27°C is
(a) 10.0 (b) 9.0
(c) 0.111 (d) 0.10

Q.41 A vessel of volume 1 m^3 contains oxygen (molecular weight = 32) at p = 1 bar and T = 47°C. The mass of oxygen in the vessel is (take universal gas constant as 8314 J/kmol-K)

(a) 40.0 kg (b) 3.0 kg
(c) 1.2 kg (d) 1.0 kg

Q.42 For water boiling at constant pressure of 1 bar, the specific heat is
(a) zero
(b) very small but positive
(c) negative
(d) infinitely large

Q.43 An inventor claims to have constructed a device that rejects 300 kJ of heat to a single reservoir while absorbing 300 kJ of work during a single cycle of the device. This device violates
(a) only the first law of thermodynamics and no other laws.
(b) only the second law of thermodynamics and no other laws.
(c) both the first and the second laws of thermodynamics.
(d) neither the first nor the second law of thermodynamics.

Q.44 A man sits on the floor by a fire burning at some distance at the same level. The mode of heat transfer mainly responsible for the man receiving heat is
(a) conduction (b) convection
(c) radiation (d) advection

Q.45 A spherical body with surface A_1 is completely enclosed by another hollow body with inner surface A_2. The shape factor of A_2 with respect to A_1 is
(a) 0.0 (b) 0.5
(c) 1.0 (d) π

Q.46 For the laminar flow of air (Prandtl number = 0.71) over a flat plate at zero incidence, the thicknesses of the velocity boundary layer δ and the thermal boundary layer δ_t are such that
(a) $\delta_t > \delta$ (b) $\delta_t = \delta$
(c) $\delta_t < \delta$ (d) $0.5 \le \delta_t/\delta \le 1.5$

Q.47 As thickness of insulation around a heated cable gradually increases from zero, heat transfer from the conductor
(a) goes on decreasing monotonically
(b) goes on increasing monotonically
(c) first increases and then decreases
(d) first decreases and then increases

Q.48 Arrangement of silver, air, aluminium and lead in the order of increasing thermal conductivity at room temperature yields
(a) air, aluminium, silver lead
(b) air, aluminium, lead, silver
(c) lead, air, aluminium, silver
(d) air, lead, aluminium, silver

Q.49 For a 2D rotational flow the Laplacian of the stream-function at any point in the flow-field.
(a) is always very large
(b) is always very small
(c) equals zero
(d) equals vorticity

Q.50 In passing through a standing normal shock-wave, a subsonic flow cannot turn supersonic as it will not satisfy the
(a) continuity equation
(b) momentum equation
(c) energy equation
(d) second law of thermodynamics

Q.51 In the fully developed laminar flow through a horizontal pipe of constant cross-section
(a) static pressure remains constant in the direction of flow.
(b) Bernoulli equation holds along the axis of the pipe.
(c) static pressure increases in the direction of flow.
(d) static pressure decreases in the direction of flow.

Q.52 For a 1 *D* compressible flow through a stream, if ρ, u and A denote density, velocity and cross-sectional area respectively, the continuity equation can be written as
(a) $\ln\rho + \ln A + \ln u - 0$
(b) $\frac{d\rho}{\rho} + \frac{dA}{A} + \frac{du}{u} = 0$
(c) $\frac{d\rho}{\rho} + \frac{dA}{A} + \frac{du}{u} \ge 0$
(d) $\rho A u^2 = a$ constant

Q.53 A pitot static tube is to measure the velocity of air-stream in a pipe. If the difference between the stagnation and static pressure as indicated by a vertical tube manometer is 12.5 cm of water, the velocity of the air-stream is (take ρ_{water} = 1000 kg/m^3 and g = 10 m/s^2)

(a) $5\sqrt{10}$ m/s (b) 50 m/s
(c) 400 m/s (d) 500 m/s

Q.54 The flight Mach number of an aircraft flying at an altitude where the temperature is –48°C is 0.7. The speed of the aircraft is (take $\gamma = 1.4$, $R = 287$ J/kgK)
(a) 100 m/s (b) 140 m/s
(c) 210 m/s (d) 250 m/s

Q.55 A cylindrical vessel of large diameter is filled with water to the brim. If a small hole is made in the wall of the vessel at a depth of 1.25 m, the velocity of outflow through the orifice is (take g = 10 m/s^2)
(a) 3.5 m/s (b) 5.0 m/s
(c) 15.0 m/s (d) 25.0 m/s

Q.56 The SI unit of the term $u^2/2g$ that appears in the Bernoulli equation is
(a) N/m^2 (b) m
(c) J/m^3 (d) bar

Q.57 For a cylindrical wooden block completely submerged under water, the only correct statement among the following is
(a) Buoyancy is the largest when the axis is horizontal.
(b) Buoyancy is the largest when the axis is vertical.
(c) Buoyancy increases with the depth at which the body is kept.
(d) Buoyancy is independent of the vertical position and orientation.

Q.58 In the converging part of a horizontal venturi meter
(a) static pressure gradually decreases.
(b) static pressure gradually increases.
(c) axial velocity gradually decreases.
(d) both the static pressure and axial velocity gradually decreases.

Q.59 A steady flow of fluid crossing a normal shock-wave undergoes a sudden rise in
(a) stagnation pressure.
(b) stagnation temperature.
(c) static pressure accompanied by a fall in static temperature.
(d) both static pressure and static temperature.

Q.60 Cavitation is a phenomenon observed
(a) only in centrifugal pumps.
(b) only in hydraulic reaction turbines like Francis and Kaplan.
(c) only in marine propellers.
(d) in all of centrifugal pumps, hydraulic reaction turbines and marine propellers.

Q.61 For an axial-flow turbine rotor with mass flow rate 10 kg/s a change in whirl of 60 m/s and a blade speed of 30 m/s, the Euler equation of turbo machines gives that the specific work done by
(a) the fluid on the rotor is 1800 J/kg
(b) the fluid on the rotor is 18000 W
(c) the turbine rotor on the fluid is 18000 J/kg
(d) the turbine rotor on the fluid is 18000 W

Q.62 In a variable speed SI engine
(a) both the torque and power are maximum at the same speed
(b) maximum torque occurs at a speed higher than that at which maximum power occurs
(c) maximum torque occurs at a speed lower than that at which maximum power occurs
(d) power goes on increasing monotonically with speed

Q.63 In an SI engine very high compression ratio cannot be used because
(a) the engine efficiency would be unmanageably high
(b) the power required for compression would be high cylinders will require very thick walls
(c) cylinder will require very thick walls
(d) self-ignition may take place before the spark occurs

Q.64 In a centrifugal compressor the stagnation temperature across the impeller
(a) increases
(b) decreases
(c) does not show a monotonic trend
(d) remains constant

Q.65 When moist air in a closed vessel is heated the specific humidity
(a) increases
(b) decreases
(c) does not show a monotonic trend
(d) remains constant

Answers DRDO-2008

1.	(b)	2.	(a)	3.	(c)	4.	(a)	5.	(b)	6.	(c)	7.	(b)	8.	(c)
9.	(b)	10.	(c)	11.	(b)	12.	(b)	13.	(a)	14.	(d)	15.	(a)	16.	(d)
17.	(b)	18.	(a)	19.	(b)	20.	(d)	21.	(d)	22.	(a)	23.	(c)	24.	(b)
25.	(a)	26.	(c)	27.	(c)	28.	(d)	29.	(b)	30.	(b)	31.	(d)	32.	(c)
33.	(d)	34.	(b)	35.	(c)	36.	(b)	37.	(a)	38.	(b)	39.	(c)	40.	(a)
41.	(c)	42.	(a)	43.	(d)	44.	(c)	45.	(b)	46.	(a)	47.	(c)	48.	(d)
49.	(d)	50.	(d)	51.	(d)	52.	(b)	53.	(b)	54.	(c)	55.	(b)	56.	(b)
57.	(d)	58.	(a)	59.	(d)	60.	(d)	61.	(b)	62.	(c)	63.	(d)	64.	(a)
65.	(d)	66.	(c)	67.	(b)	68.	(c)	69.	(d)	70.	(d)	71.	(c)	72.	(d)
73.	(c)	74.	(d)	75.	(c)	76.	(a)	77.	(a)	78.	(a)	79.	(b)	80.	(a)
81.	(b)	82.	(a)	83.	(a)	84.	(b)	85.	(b)	86.	(b)	87.	(a)	88.	(a)
89.	(a)	90.	(a)	91.	(c)	92.	(b)	93.	(b)	94.	(d)	95.	(c)	96.	(a)
97.	(b)	98.	(a)	99.	(c)	100.	(a)	101.	(d)	102.	(a)	103.	(c)	104.	(a)
105.	(c)	106.	(d)	107.	(b)	108.	(c)	109.	(b)	110.	(a)	111.	(d)	112.	(c)
113.	(a)	114.	(d)	115.	(a)	116.	(c)	117.	(b)	118.	(d)	119.	(a)	120.	(a)
121.	(b)	122.	(c)	123.	(d)	124.	(b)	125.	(c)	126.	(d)	127.	(b)	128.	(a)
129.	(b)	130.	(b)	131.	(c)	132.	(b)	133.	(b)	134.	(c)	135.	(a)	136.	(b)
137.	(a)	138.	(d)	139.	(a)	140.	(b)	141.	(d)	142.	(b)	143.	(c)	144.	(a)
145.	(d)	146.	(c)	147.	(d)	148.	(c)	149.	(b)	150.	(c)				

Explanations DRDO-2008

2. (a)

For spherical tank
hoop stresses

$$\sigma_t = \frac{pd}{4t} \le 125$$

$$p \le 125 \times \frac{4t}{d}$$

or $$p \le 125 \times \frac{4 \times 10}{20000}$$

or $$p \le 0.25 \text{ MPa}$$

$$p_{max} = \textbf{0.25 MPa}$$

3. (c)

Natural frequency con.

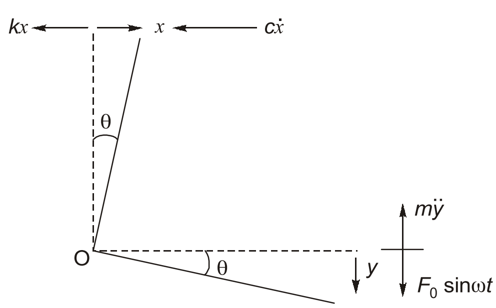
$$\omega_n = \sqrt{\frac{g}{\Delta}}$$

For a cantilever beam

$$\Delta = \frac{MgL^3}{3EI}$$

$$\omega_n = \sqrt{\frac{3EI}{(ML^3)}} \text{ rad/s}$$

4. (a)



$$\frac{x}{a} = \frac{y}{b} = \theta$$

$$x = \frac{a}{b}y$$

$$\Sigma M_o = 0 \text{ (moment about pivot point)}$$

$$\Rightarrow (m\ddot{y})b + kxa + c\dot{x}a = F_0 b \sin\omega t$$

$$\Rightarrow mb^2\ddot{\theta} + ka^2\theta + ca^2\dot{\theta} = F_0 b \sin\omega t$$

Undamped natural frequency,

$$\omega_n = \left(\frac{ka^2}{mb^2}\right)^{1/2} = \frac{a}{b}\sqrt{\frac{k}{m}}$$

5. (b)

On comparing given equation with

$$\ddot{x} + 2(\xi\omega_n)\dot{x} + \omega_n^2 x = 0$$

We will get

$$2\xi\omega_n = 20 \text{ and } \omega_n = 9$$

$$\Rightarrow \quad \xi\omega_n = 10$$

$$\xi = \frac{10}{9} = 1.1$$

$$\xi > 1$$

(Hence system is overdamped)

7. (b)

Shear stress

$$\tau = \frac{P}{0.707hl} = \frac{12000}{0.707 \times 6 \times 50}$$

$$= \textbf{56.57 N/mm}^2$$

$$\text{FOS} = \frac{\text{yield strength/2}}{\text{shear stress induced}}$$

$$= \frac{180 \times 10^6}{56.57 \times 10^6} = \textbf{3.18}$$

9. (b)

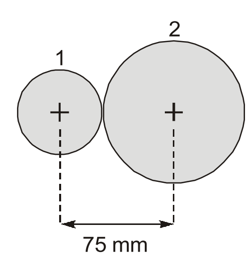
Velocity of piston

$$V_p = \omega r\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)$$

In this case $\theta = 90°$, $V_p = \omega r$

$$r = \frac{V_p}{\omega} = \frac{2}{20} = 0.1 \text{ m} = \textbf{10 cm}$$

10. (a)



By law of gearing

$$\omega_1 r_1 = \omega_2 r_2$$

$$\omega_2 = 0.5\,\omega_2$$

$$\therefore \quad r_1 = 0.5\, r_2$$

$$r_1 + r_2 = 75$$

$$1.5\, r_2 = 75 \Rightarrow r_2 = 50 \text{ mm}, d_2 = 100 \text{ mm}$$

$$r_1 = 25 \text{ mm}, d_1 = 50 \text{ mm}$$

11. (b)

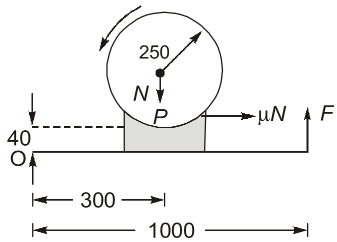
Shearing area = hub length (or key length)
× width of key (or side of square key)
$= l \times d$

$$\text{Torque, } T = \tau(ld) \times \frac{D}{2}$$

$$d = \frac{2T}{\tau l D} = \frac{2\times500\times1000}{50\times50\times40}$$

$= 10$ mm

12. (b)



(All dimensions are in mm)

Taking moment about 0.

$\Sigma M_o = 0$

$\Rightarrow F(1000) - N(300) - \mu N(40) = 0$

$\Rightarrow F(1000) = 300\text{ N} + 12\text{ N}$

$\Rightarrow F = $ **0.312 N**

Resisting torque,

$T = 300 \times 10^3$ Nmm

$T = (\mu N)R$

Normal reaction

$\therefore\ N = \dfrac{300\times10^3}{0.3\times250} = 4000\text{ N}$

$\therefore\ F = 0.312 \times 4000 = $ **1248 N**

13. (a)

Angular acceleration given by

$a = r\alpha$

$\alpha = \dfrac{a}{r} = \dfrac{0.225}{0.075} = $ **3 rad/s²**

15. (a)

$$\frac{P_1}{P_2} = \frac{k_1}{k_2} = \frac{200}{160} = \frac{5}{4}$$

$P_1 + P_2 = 1800$

$\left(1+\dfrac{5}{4}\right)P_2 = 1800$

$P_2 = 800$ N

$P_2 = k_2 x$

$800 = 160\,x$

$x = $ **5 mm**

16. (d)

Tearing efficiency $= \dfrac{P-d}{P}\times100$

$= \dfrac{60-18}{60}\times100 = $ **70%**

18. (a)

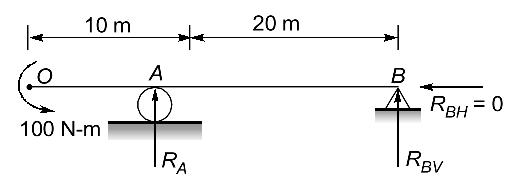
From momentum conservation

$m_1 V_1 = m_2 V_2 + m_1 V_f$

$20(20) = 35(10) + 20(V_f)$

$V_f = $ **2.5 m/s**

20. (d)



$R_A + R_{Bv} = 0$

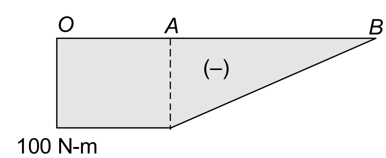
$\Sigma M_B = 0$

$-100 + R_A \times 20 = 0$

$R_A = 5$ N

$R_{Bv} = -5$ N

BMD



Bending moment at roller support

$= 100$ N-m

23. (c)

$$\sigma_{max} = \frac{P}{A_{min}}$$

$\sigma_{max} \le \sigma_{allowable}$

$\dfrac{P}{A_{min}} \le \sigma_{allowable}$

$\dfrac{P}{0.5} \le 100\times10^6$

$P \le 50$ MN

24. (b)

$$\frac{\tau_x}{r_x} = \frac{T}{J} = \frac{G\theta}{l}$$

r_x - radial distance from axis of shaft.

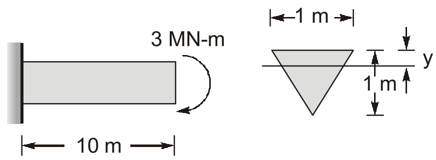
25. (a)

$$\epsilon_x = \frac{\sigma_x - \nu(\sigma_y)}{E}$$

$$\epsilon_x = \frac{(1-\nu)\,\sigma_x}{E}$$

$$\frac{\sigma_x}{\epsilon_x} = \frac{E}{1-\nu}$$

26. (c)



$$\sigma_b = \frac{M\,y}{I}$$

$$y = \frac{1}{3}\text{m}$$

$$I = \frac{bd^3}{36} = \frac{1\times 1^3}{36} = \frac{1}{36}\ \text{m}^4$$

$$M = 3\times 10^6\ \text{Nm}$$

$$\sigma_b = \frac{3\times 10^6 \times 1}{3\times\frac{1}{36}} = \textbf{36 MPa}$$

27. (c)

$$P_{cr} = \frac{\pi^2 EI}{L^2}\ \text{(Hinged-hinged end condition)}$$

$P_{cr} = EI$ (Taking I as least moment of inertia)

$= 100 \times 10^9 \times 100 \times 10^{-8}$

$= 100000$ N = **100 kN**

28. (d)

Proportionality limit is the point upto which the stress remains directly proportional to strain whereas elastic limit is the point upto which the material remains elastic i.e. if the stress is removed within elastic limit, then the material will regain its original shape and size.

30. (b)

Point of contraflexure is a point where the curvature of beam changes sign and occurs at a point where the B.M. is zero.

31. (d)

Bulk hardness of rigidity

$$E = 3\,K(1 - 2\nu)$$

$K \to \infty$ for $\nu = 0.5$

it means material is rigid so no volume change occurs.

32. (c)

Radius of Mohr circle

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

$$= \sqrt{\left(\frac{70-60}{2}\right)^2 + 25}$$

$$= 5\sqrt{2}\ \text{MPa}$$

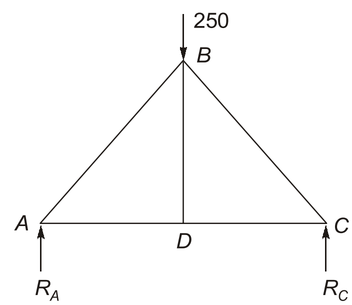
33. (d)

Due to axis of symmetry,

$$I_{xy} = 0$$

x - y axis is at centroid

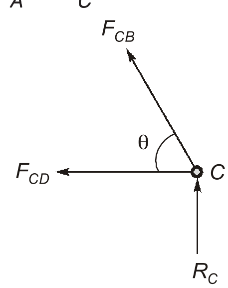
35. (c)



$$R_A + R_C = 250$$

$$R_A = R_C \quad \left(\sum M_D = 0\right)$$

$$\mathbf{R_A = R_C = 125\ kN}$$

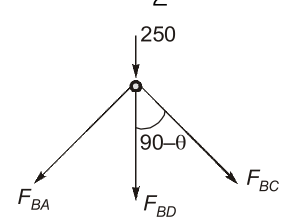


$$F_{CB} \sin\theta = -R_C$$

$$F_{CB} = -\frac{125}{2}\times\sqrt{20}$$

$$\sin\theta = \frac{2}{\sqrt{4^2+2^2}} = \frac{2}{\sqrt{20}}$$

$$\mathbf{F_{AB}} = -\frac{125\sqrt{20}}{2}$$



$$2\,F_{BC}\sin\theta + F_{BD} = 250$$

$$2\times\frac{125\sqrt{20}}{2}\times\frac{2}{\sqrt{20}} + F_{BD} = 250$$

$$F_{BD} = 0$$

BD is zero force member.

36. (b)

Displacement velocity

$$x = \frac{5t^2}{2} - 20t + 10$$

$$\dot{x} = 5t - 20$$

$$0 = 5t - 20$$

$$t = 4 \text{ sec.}$$

$$x = ? \text{ at } t = 4$$

So displacement

$$x = \frac{5}{2} \times 16 - 20(4) + 10 = \mathbf{-30\ m}$$

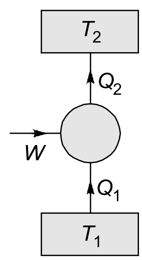
40. (a)

$$T_1 = -3°C = 270 \text{ k}$$

$$T_2 = 27°C = 300 \text{ k}$$

$$(COP)_{HP} = \frac{Q_2}{Q_2 - Q_1}$$

$$= \frac{T_2}{T_2 - T_1} = \frac{300}{30} = 10$$



41. (c)

Ideal gas equation

$$pV = mRT$$

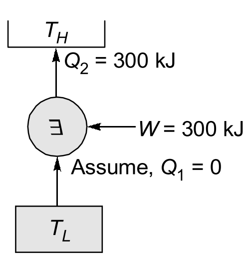
$$R = \frac{\bar{R}}{M}$$

$$1 \times 10^5 \times 1 = m \times \frac{8314}{32}(273 + 48)$$

$$m = \mathbf{1.199\ kg}$$

43. (a)

It is case of electric heater and it is possible without violating any law of thermodynamics.

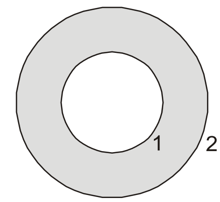


45. (b)

$$A_1 F_{12} = A_2 F_{21}$$

$$F_{21} = \frac{A_1}{A_2} F_{12} \qquad (\therefore F_{12} = 1)$$

$$F_{21} = \frac{A_1}{A_2}$$



As $A_2 > A_1$, $F_{21} < 1$ from the given option (b) is only less than one.

F_{21} can not be zero as this will lead to trivial solution.

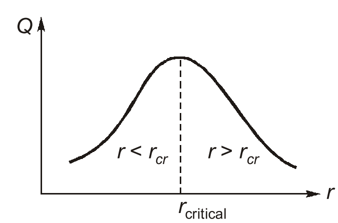
46. (a)

Prandtl law,

$$Pr = \left(\frac{\delta}{\delta_T}\right)^3$$

$$\frac{\delta}{\delta_T} = (0.71)^{1/3} = \mathbf{0.89}$$

47. (c)



53. (b)

$$h = x\left[\frac{\rho_{water}}{\rho_{air}} - 1\right] = 0.125 \times 999 \text{ m}$$

$$V = \sqrt{2gh}$$

$$= \sqrt{2 \times 10 \times 0.125 \times 999} = \mathbf{49.975\ m/s}$$

54. (c)

$$\text{Mach number} = \frac{V}{\sqrt{\gamma RT}} = 0.7$$

$$\frac{V}{\sqrt{1.4 \times 287 \times 225}} = 0.7$$

$$V = \mathbf{210.472\ m/s}$$

55. (b)

$$V = \sqrt{2gh}$$

$$= \sqrt{2 \times 10 \times 1.25} = \mathbf{5\ m/s}$$

ME

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Q.1 In nodular iron, graphite is in the form of
(a) Cementite (b) Free carbon
(c) Flakes (d) Spheroids

Q.2 Hardness of steel depends on
(a) Amount of carbon it contains
(b) The shape and distribution of the carbides in iron
(c) Method of fabrication
(d) Contents of alloying elements

Q.3 Too high welding current in arc welding would result in
(a) Excessive spatter, under cutting along edges, irregular deposits, wasted electrodes
(b) Excessive piling up of weld metal, poor penetration, wasted electrodes
(c) too small bead, weak weld and wasted electrodes
(d) excessive piling up of weld metal, overlapping without penetration of edges, wasted electrodes

Q.4 Which of the following processes would produce strongest components?
(a) Hot rolling (b) Extrusion
(c) Cold rolling (d) Forging

Q.5 If a quantity Q is dependent on three other quantities q_1, q_2 and q_3 related such that $Q = K \times (q_1)^{n_1} \times (q_2)^{n_2} \times (q_3)^{n_3}$ then overall error $\frac{\delta Q}{Q} =$

(a) $n_1\left(\frac{\delta q_1}{q_1}\right) + n_2\left(\frac{\delta q_2}{q_2}\right) + n_3\left(\frac{\delta q_3}{q_3}\right)$

(b) $\frac{1}{n_1}\frac{\delta q_1}{q_1} + \frac{1}{n_2}\frac{\delta q_2}{q_2} + \frac{1}{n_3}\frac{\delta q_3}{q_3}$

(c) $\frac{\delta q_1}{q_1} + \frac{\delta q_2}{q_2} + \frac{\delta q_3}{q_3}$

(d) $\left(\frac{\delta q_1}{q_1}\right)^{n_1} + \left(\frac{\delta q_2}{q_2}\right)^{n_2} + \left(\frac{\delta q_3}{q_3}\right)^{n_3}$

Q.6 Which of the following has maximum hardness
(a) Austenite (b) Pearlite
(c) Troostite (d) Martensite

Q.7 The main advantage of line organization is its
(a) Effective command and control
(b) Defined responsibilities at all levels
(c) Rigid discipline in the organization
(d) All of the above

Q.8 The mathematical technique for finding the best use of limited resources in an optimum manner is known as
(a) Operation research
(b) Linear programming
(c) Network analysis
(d) Queuing theory

Q.9 Which of the following errors are generally distributed in accordance with the Gaussian distribution
(a) Controllable errors (b) Calibration errors
(c) Avoidable errors (d) Random errors

Q.10 $\frac{PL^3}{3EI}$ is the deflection under the load P of a cantilever beam (length L, modulus of elasticity E, moment of inertia I). The strain energy due to bending is

(a) $\frac{P^2L^3}{3EI}$ (b) $\frac{P^2L^3}{6EI}$

(c) $\frac{P^2L^3}{4EI}$ (d) $\frac{P^2L^3}{48EI}$

Q.11 A mass m attached to a light spring oscillates with a period of 2 sec. If the mass is increased by 2 kg, the period increases by 1 sec. The value of m is
(a) 1 kg (b) 1.6 kg
(c) 2 kg (d) 2.4 kg

Q.12 A short column external diameter D and internal diameter d carries an external load W. The greatest eccentricity which the load can have without producing tension on the cross-section of the column is

(a) $(D + d)/8$ (b) $(D^2 + d^2)/8$
(c) $(D^2 + d^2)/8D$ (d) $(D^2 + d^2)/8d$

Q.13 If the radius of wire stretched by a load double, then its Young's modulus will

(a) be doubled (b) be halved
(c) become four times (d) none of the above

Q.14 Longitudinal stress in a thin cylinder subjected to internal pressure is

(a) half of the hoop stress
(b) twice the hoop stress
(c) equal to the hoop stress
(d) one-fourth the hoop stress

Q.15 Maximum deflection in cantilever due to pure bending moment M at its end is

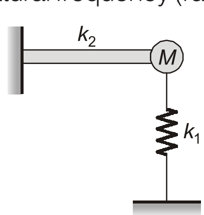
(a) $\frac{ML^2}{2EI}$ (b) $\frac{ML^2}{3EI}$

(c) $\frac{ML^2}{4EI}$ (d) $\frac{ML^2}{6EI}$

Q.16 If Poisson's ratio for a material is 0.5, then the elastic modulus for the material is

(a) 3 times its shear modulus
(b) 4 times its shear modulus
(c) equal to its shear modulus
(d) indeterminate

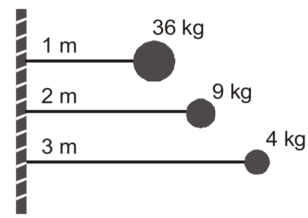
Q.17 A cantilever beam of negligible weight is carrying a mass M at its free end, and is also resting on an elastic support of stiffness k_1 as shown in the figure below. If k_2 represents the bending stiffness of the beam, the natural frequency (rad/s) of the system is



(a) $\sqrt{\frac{(k_1 k_2)}{M(k_1 + k_2)}}$ (b) $\sqrt{2(k_1 + k_2)/M}$

(c) $\sqrt{(k_1 + k_2)/M}$ (d) $\sqrt{(k_1 - k_2)/M}$

Q.18 The figure shows 3 small spheres that rotate about a vertical axis. The perpendicular distance between the axis and the center of each sphere is given. Mass of highest rotational inertia about that axis, is

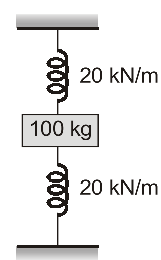


(a) 36 (b) 4
(c) 9 (d) All same

Q.19 Which of the following relationships between the force F on a particle and the particles position x implies simple harmonic oscillation

(a) $F = -7x$ (b) $F = 200x^2$
(c) $F = 10x$ (d) $F = 5x^2$

Q.20 A mass of 100 kg is held between two springs as shown in figure. The natural frequency of vibration of the system in cycles/seconds is



(a) $\frac{10}{\pi}$ (b) $\frac{5}{\pi}$

(c) $\frac{1}{2\pi}$ (d) $\frac{20}{\pi}$

Q.21 The bending equation is written as

(a) $\frac{I}{M} = \frac{f}{y} = \frac{E}{R}$ (b) $\frac{M}{I} = \frac{f^2}{y} = \frac{E^2}{R^2}$

(c) $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$ (d) $\frac{M^2}{I} = \frac{f^2}{y} = \frac{E^2}{R}$

Q.22 Hydraulic testing of boilers is done at pressures

(a) below and above atmosphere
(b) slightly above atmospheric pressure
(c) at half the working pressure of boiler
(d) at 1.5 to 2 times the working pressure

Q.23 100 m of water column is equal to

(a) 1000 kN/m^2 (b) 100 kN/m^2
(c) 10 kN/m^2 (d) 1 kN/m^2

Q.24 Gantry girders are invariably designed to resist
(a) transverse loads only
(b) lateral loads only
(c) transverse and lateral loads
(d) transverse, lateral and axial load

Q.25 If the rotating mass of a rim type flywheel is distributed on another rim, type flywheel whose mean radius is half the mean radius of the former, then energy stored in the later at the same speed will be
(a) four times the first one
(b) same as the first one
(c) one fourth of the first one
(d) one and a half times the first one

Q.26 A thin circular disc is rolling with a uniform linear speed, along a straight path on a plane surface. Consider the following statements in this regard:
1. All points of the disc have the same velocity.
2. The center of the disc has zero acceleration.
3. The center of the disc has centrifugal acceleration.
4. The point on the disc making contact with the plane surface has zero acceleration.

Of these statements
(a) 1 and 4 are correct
(b) 3 and 4 are correct
(c) 3 alone is correct
(d) 2 alone is correct

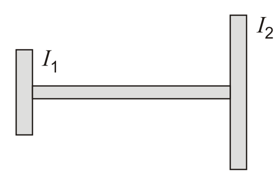
Q.27 If a number of forces act on a rigid body, each force may be replaced by an equal and parallel force acting through a fixed point, together with a couple. For the rigid body to be in equilibrium
(a) both resultant force and couple must be zero
(b) the resultant couple on the body must be zero
(c) the resultant force at the fixed point must be zero
(d) none of the above need be zero

Q.28 Whirling speed of a shaft coincides with the natural frequency of its
(a) longitudinal vibration
(b) transverse vibration
(c) torsional vibration
(d) coupled bending torsional vibration

Q.29 A fixed gear having 200 teeth is in mesh with another gear having 50 teeth. The two gears are connected by an arm. The number of turns made by the smaller gear for one revolution of arm about the center of the bigger gear is
(a) 4 (b) 3
(c) $\frac{2}{4}$ (d) 5

Q.30 With symbols having the usual meanings, the single degree of freedom system, $m\ddot{x} + c\dot{x} + kx = F\sin\omega t$ represents
(a) free vibrations with damping
(b) free vibrations without damping
(c) forced vibrations with damping
(d) forced vibrations without damping

Q.31 In the two-rotor system shown in the figure, ($I_1 < I_2$), a node of vibration is situated



(a) between I_1 and I_2 but nearer to I_1
(b) between I_1 and I_2 but nearer to I_2
(c) exactly in the middle of the shaft
(d) nearer to I_1 but outside

Q.32 Which one of the following is not a friction clutch?
(a) Disc or plate clutch
(b) Cone clutch
(c) Centrifugal clutch
(d) Jaw clutch

Q.33 Polar moment of inertia (I_p) of a circular disc is to be determined by suspending it by a wire and noting the frequency of oscillations (f)
(a) $I_p \propto \frac{1}{f^2}$ (b) $I_p \propto f^2$
(c) $I_p \propto f$ (d) $I_p \propto \frac{1}{f}$

Q.34 Pick up the wrong statement. A flywheel
(a) is used to limit the inevitable fluctuation of speed during each cycle
(b) controls the mean speed of rotation
(c) stores up energy and gives up whenever required
(d) regulates the speed during one cycle of a prime mover

Q.35 Purpose of using differential gear in automobile is to
(a) help in turning
(b) control speed
(c) avoid jerks
(d) obtain rear movement

Q.36 The acceleration of Simple Harmonic Motion of a pendulum is proportional to
(a) length of pendulum
(b) time period
(c) angular velocity
(d) displacement

Q.37 A person walks up a stalled escalator in 90 seconds. When standing on the same escalator, now moving, he is carried up in 60 seconds. How much time would it take him to walk up the moving escalator?
(a) 30 sec (b) 36 sec
(c) 45 sec (d) 54 sec

Q.38 A stone of mass m at the end of a string of length l is whirled in a vertical circle at a constant speed. The tension in the string will be maximum when the stone is
(a) At the top of the circle
(b) Half-way down from the top
(c) Quarter-way down from the top
(d) At the bottom of the circle

Q.39 Speed of particle executing simple harmonic motion with amplitude α is half of the maximum speed. At that instant, displacement of the particle is

(a) $\frac{\alpha}{2}$ (b) $\frac{\sqrt{3}}{2}\alpha$

(c) $\frac{2\alpha}{\sqrt{3}}$ (d) $3\sqrt{2}\alpha$

Q.40 Two satellites, of masses m and 2 m, are on the same circular orbit around earth. If the velocity of the lighter satellite is v_0, what is the velocity of the heavier satellite?

(a) $\frac{1}{2}v_0$ (b) v_0

(c) $2v_0$ (d) $\frac{1}{4}v_0$

Q.41 $Nu = CR_e^m P_r^n$ represents heat transfer under
(a) Free convection
(b) Forced convection
(c) Combined convection
(d) None of the above

Q.42 If the inner and outer surfaces of a hollow cylinder (having radii r_1 and r_2 and length L) are at temperatures t_1 and t_2 then rate of radial heat flow will be

(a) $\frac{k}{2\pi L}\frac{t_1 - t_2}{\log\frac{r_2}{r_1}}$ (b) $\frac{1}{2\pi Lk}\frac{t_1 - t_2}{\log\frac{r_2}{r_1}}$

(c) $\frac{2\pi L}{k}\frac{t_1 - t_2}{\log\frac{r_2}{r_1}}$ (d) $2\pi Lk\frac{t_1 - t_2}{\log\frac{r_2}{r_1}}$

Q.43 For infinite parallel planes with emissivities ε_1 and ε_2, the interchange factor for radiation from surface 1 to surface 2 is given by

(a) $\frac{\varepsilon_1\varepsilon_2}{\varepsilon_1 + \varepsilon_2 - \varepsilon_1\varepsilon_2}$ (b) $\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2}$

(c) $\varepsilon_1 + \varepsilon_2$ (d) $\varepsilon_1\varepsilon_2$

Q.44 For a closed system, difference between the heat added to the system and work done by the gas, is equal to the change in
(a) internal energy (b) entropy
(c) enthalpy (d) temperature

Q.45 The condition for reversibility of a cycle is

(a) Cyclic$\int\frac{dQ}{T} < 0$ (b) Cyclic$\int\frac{dQ}{T} > 0$

(c) Cyclic$\int\frac{dQ}{T} = 0$ (d) None of these

Q.46 The state of a real gas if changed from pressure p_1, temperature T_1 to pressure p_2 temperature T_2. The change in enthalpy, $h_1 - h_2$, is given by

(a) $\int_{T_1}^{T_2} c_p\,dT$

(b) $\int_{T_1}^{T_2} c_p\,dT + \int_{p_1}^{p_2}\left(\frac{\partial V}{\partial p}\right)_T dp$

(c) $\int_{T_1}^{T_2} c_p\,dT + \int_{p_1}^{p_2}\left[V - T\left(\frac{\partial V}{\partial T}\right)_p\right]dp$

(d) $\int_{T_1}^{T_2} c_p\,dT + \int_{p_1}^{p_2}\left[V - T\left(\frac{dV}{dT}\right)_p\right]dp$

Answers ISRO-2006

1.	(d)	2.	(a)	3.	(a)	4.	(d)	5.	(a)	6.	(d)	7.	(d)	8.	(b)
9.	(b)	10.	(b)	11.	(b)	12.	(c)	13.	(d)	14.	(a)	15.	(a)	16.	(a)
17.	(c)	18.	(d)	19.	(a)	20.	(a)	21.	(c)	22.	(d)	23.	(a)	24.	(c)
25.	(c)	26.	(d)	27.	(a)	28.	(b)	29.	(d)	30.	(c)	31.	(b)	32.	(d)
33.	(a)	34.	(b)	35.	(a)	36.	(d)	37.	(b)	38.	(d)	39.	(b)	40.	(a)
41.	(b)	42.	(d)	43.	(a)	44.	(a)	45.	(c)	46.	(c)	47.	(b)	48.	(a)
49.	(c)	50.	(b)	51.	(a)	52.	(*)	53.	(d)	54.	(d)	55.	(c)	56.	(d)
57.	(b)	58.	(a)	59.	(d)	60.	(c)	61.	(b)	62.	(c)	63.	(c)	64.	(d)
65.	(c)	66.	(c)	67.	(b)	68.	(a)	69.	(a)	70.	(b)	71.	(c)	72.	(c)
73.	(d)	74.	(a)	75.	(c)	76.	(b)	77.	(c)	78.	(c)	79.	(b)	80.	(c)

Explanations ISRO-2006

5. (a)

$$Q = K \times (q_1)^{n_1} \times (q_2)^{n_2} \times (q_3)^{n_3}$$

$$\ln Q = \ln K + n_1 \ln q_1 + n_2 \ln q_2 + n_3 \ln q_3$$

$$\frac{dQ}{Q} = n_1\left(\frac{dq_1}{q_1}\right) + n_2\left(\frac{dq_2}{q_2}\right) + n_3\left(\frac{dq_3}{q_3}\right)$$

7. (d)

Merits of line organization:

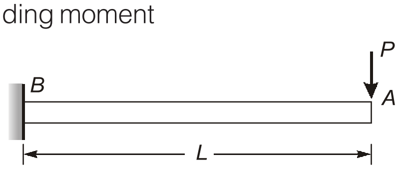
- Simplicity
- Clear-cut division of authority and responsibility
- Strong discipline
- Unified control
- Prompt decisions
- Flexibility

10. (b)

for an end loaded cantilever,

$$M = -Px$$

Bending moment



$$U = \int_0^L \frac{M^2 dx}{2EI} = \int_0^L \frac{(Px)^2 dx}{2EI}$$

$$= \frac{P^2}{2EI}\int_0^L x^2 dx = \frac{P^2L^3}{6EI}$$

Alternative approach:

$$U = \frac{1}{2} \times P \times \Delta$$

$$= \frac{1}{2} \times P \times \frac{PL^3}{3EI} = \frac{P^2L^3}{6EI}$$

11. (b)

Time period,

$$T_1 = 2\pi\sqrt{\frac{m}{K}} = 2 \quad \text{...(i)}$$

When mass in increases by 2 kg

$$T_2 = 2\pi\sqrt{\frac{m+2}{K}} = 3 \quad \text{...(ii)}$$

From Eqs. (i) and (ii)

$$\frac{m}{m+2} = \frac{4}{9}$$

$$\Rightarrow \quad m = 1.6 \text{ kg}$$

12. (c)

$$\sigma_b = \sigma_a$$

$$\frac{M}{Z} = \frac{4P}{\pi(D^2 - d^2)}$$

$$\frac{64e \cdot D}{2\pi(D^4 - d^4)} = \frac{4P}{\pi(D^2 - d^2)}$$

$$e = \frac{D^2 + d^2}{8D}$$

13. (d)

Young's modulus is material property not the geometric property.

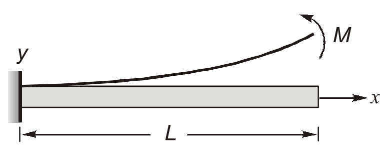
14. (a)

$$\sigma_h = \frac{Pd}{2t}$$

$$\sigma_L = \frac{Pd}{4t}$$

$$\sigma_L = \frac{1}{2}\sigma_h$$

15. (a)



for $0 < x < L$,

$$y(x) = \left(\frac{ML^2}{2EI}\right)\left(\frac{x}{L}\right)^2$$

$$y_{max} \text{ at } x = L = \frac{ML^2}{2EI}$$

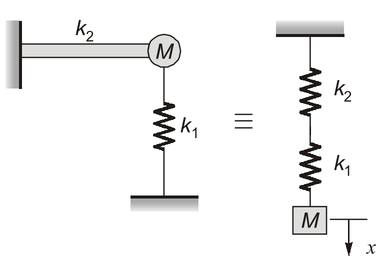
16. (a)

$$G = \frac{E}{2(1+\nu)}$$

$$\nu = 0.5 \quad \text{(given)}$$

$$G = \frac{E}{2(1.5)} = \frac{E}{3}$$

17. (c)



Two springs are in parallel, so

$$k_{eff} = k_1 + k_2$$

$$\omega = \sqrt{\frac{k_{eff}}{M}} = \sqrt{\frac{k_1 k_2}{(k_1 + k_2)M}}$$

18. (d)

Rotational Inertia,

$$I = \text{mass} \times \text{radius}^2$$

$$I_1 = m_1 r_1^2 = 36 \times 1^2 = 36 \text{ kgm}^2$$

$$I_2 = m_2 r_2^2 = 9 \times 2^2 = 36 \text{ kgm}^2$$

$$I_3 = m_3 r_3^2 = 9 \times 3^2 = 36 \text{ kgm}^2$$

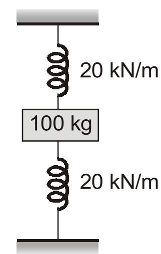
Since, $I_1 = I_2 = I_3$

$\therefore$ All same

19. (a)

$$\because \quad F = -kx$$

20. (a)



Both the springs are in parallel,

$$k_{eff} = k_1 + k_2$$

$$k_{eff} = 40 \text{ kN/m}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k_{eff}}{m}} = \frac{1}{2\pi}\sqrt{\frac{40 \times 10^3}{100}} = \frac{10}{\pi}$$

23. (a)

$$p = \rho g h = 9810 \times 100 \text{ N/m}^2$$

$$= 981 \text{ kN/m}^2$$

25. (c)

Energy, $E = \frac{1}{2}I\omega^2$

for rim type flywheel,

$$I = mR^2$$

Now, $E_1 = \frac{1}{2}mR_1^2\omega^2$

$$E_2 = \frac{1}{2}m\left[\frac{R_1}{2}\right]^2 \omega^2 \text{ [for same speed]}$$

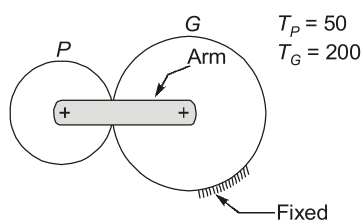
$$\therefore \quad E_2 = \frac{1}{4 \times 2}mR_1^2\omega^2$$

Hence, $E_2 = \frac{1}{4}E_1$

26. (d)

1. All points of the disc rotate with different velocities. Velocity is maximum at the top and zero at the contact point.
2. The center of the disc moves with the average velocity of the points of the top and the bottom. Centre point is stationary and does not change direction. So, there is no acceleration.
3. As centre point has no acceleration then it has no centrifugal acceleration.
4. The point on the disc making contact with the ground has zero velocity. Therefore, it has zero acceleration.

29. (d)



Step No	Arm	Pinion	Gear
Fixed arm	0	+ 1	$-T_P/T_G$
x rotate	0	$+x$	$-x\, T_P/T_G$
y	y	$x+y$	$y - x\, T_P/T_G$

$N_G = 0$, (Given)

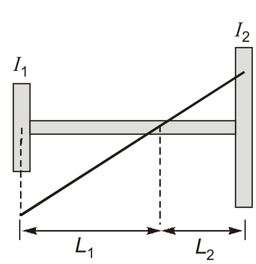
$$y - \frac{x}{4} = 0,$$

$$y = \frac{x}{4}$$

$$y = 1,\ x = 4 \text{ rev.}$$

$$N_P = 4 + 1 = 5 \text{ rev.}$$

31. (b)



Node point is found out by

$$I_1 L_1 = I_2 L_2$$

$$\because \quad I_2 > I_1$$

$$\therefore \quad L_2 < L_1$$

So, the node of vibration is situated nearer to I_2.

33. (a)

Radius of gyration,

$$k \propto \frac{1}{f_n}$$

$$\therefore \quad I \propto \frac{1}{f_n^2}$$

34. (b)

A flywheel controls the speed variation caused by the engine whereas governor maintains a constant speed during load variation on the engine.

37. (b)

Let speed of person = u

Speed of escalator = v

Distance to be moved = s

$$\frac{s}{u} = 90 \quad \ldots(i)$$

$$\frac{s}{v} = 60 \quad \ldots(ii)$$

By relative velocity approach.

Time taken by person to walk up moving escalator

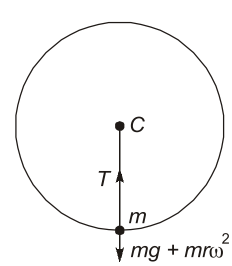
$$= \frac{s}{u+v}$$

From Eqs. (i) and (ii)

$$\frac{u+v}{s} = \frac{1}{90} + \frac{1}{60} = \frac{5}{180}$$

$$\frac{s}{u+v} = 36\ s$$

38. (d)



At the bottom of the circle, tension will be maximum.

Tension in the string will be

$$T = mg + m\omega^2 r$$