S'11 : 3 FN : AN 205 (1405)

MECHANICAL SCIENCE

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A**, ANY TWO *from* **Group B** *and* ALL *from* **Group C**.

All parts of a question (a, b, etc.) should be answered at one place.

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Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) What is a vector? Why is 'force' considered to be a vector? Is energy a vector? 4

(*b*) The system of forces, all in newtons, is shown in Fig. 1. Determine the magnitude and direction of the resultant force. 8

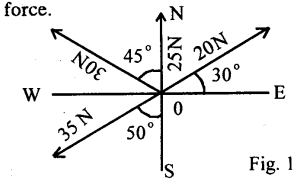


Fig. 1

(Turn Over)

(*c*) A lever AB rests horizontally on a fulcrum at C such that AC = *a* and CB = *b*. Two loads, each of magnitude *Q*, are acting on the left of C, one at the free end A and the other mid-way between A and C. Three loads, each of magnitude *P*, are acting on the right of C, one at the free end B, the second at a distance of *b*/3 on the left of B and the third at a distance of *b*/3 on the right of C. If *Q* = 2*P* and the weight of lever is negligible, determine the ratio *a* : *b* of an arm of the lever if it is in equilibrium. 8

2. (*a*) Find the centre of gravity of the E-section shown in Fig.2 with respect to the point O. All dimensions are in mm. 6

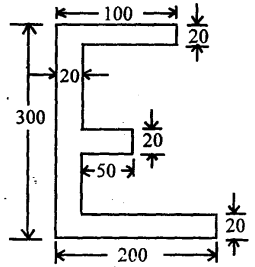


Fig. 2

(*b*) Define the radius of gyration. Determine the moment of inertia of an inverted T-section of a flange of 100 mm × 10 mm and web of 120 mm × 12 mm about both the centroidal axes (Fig. 3). 6

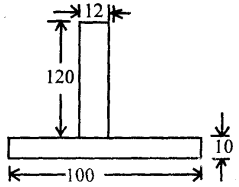
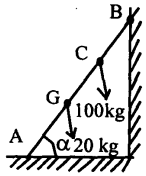


Fig. 3

(*c*) A ladder, shown in Fig. 4, is 4 m long and is supported by a horizontal floor and a vertical wall. The coefficient of friction at the wall is 0·25 and at the floor is 0·50. The weight of the ladder is 20 kg considered concentrated at G . The ladder also supports a vertical load of 100 kg at C. Determine the reactions at A and B and compute the least value of α at which the ladder may be placed without slipping to the left. 8



AG = 2 m , AB = 4 m
BC = 1 m

Fig. 4

3. (*a*) Derive an expression for the time taken by a body, projected vertically upwards with a velocity *u*, to reach a height *h*. 4

(*b*) A stone after falling from rest for 4 sec breaks a glass plane and in breaking it looses 25% of its velocity. How far will it fall in the next second? 4

(*c*) A cricket ball thrown from a height of 1·8 m at an angle of 30° from the horizontal with a velocity of 18 m/s is caught by a fieldsman at a height of 60 cm from the ground. How far apart were the two men? 6

(*d*) An engine of mass 50 tonnes pulls a train of mass 250 tonnes up a gradient of 1 in 120 with a uniform speed of 36 kmph. Find the power exerted by the engine, if the tractive resistance is 60 N per tonne. 6

4. (*a*) Draw the stress-strain diagrams of mild steel and cast iron and explain the difference. 5

(*b*) Define the following : (*i*) Modulus of elasticity, (*ii*) Modulus of rigidity, (*iii*) Bulk modulus, and (*iv*) Poisson's ratio. 5

(*c*) What is strain energy? Show that the strain energy per unit volume is $\sigma^2/2E$. 4

(*d*) A point is subjected to a tensile stress of $60\,kN/m^2$ and a compressive stress of $40\,kN/m^2$, acting on two mutually perpendicular planes, and a shear stress of $12\,kN/m^2$ on these planes. Determine the principal stresses as well as the maximum shear stress. 6

Group B

5. (*a*) What do you mean by capillarity? Estimate the rise of water in a capillary tube of 1 mm inner radius at 20°C. Given : $\sigma = 7{\cdot}28 \times 10^{-2}$ N/m. 4

(*b*) A conical tube is fixed vertically with its smaller end upwards and it forms a part of a pipeline. The velocity at the smaller end is 4·5 m/s and at the larger it is 1·5 m/s. The length of the conical tube is 1·5 m. The pressure at the upper end is equivalent to a head of 10 m of water. Neglecting friction, determine the pressure at the lower end of the tube. 6

(*c*) A circular plate of 1 m diameter is immersed in water so that the vertical distance of its perimeter lies between 0·5 m and 1·5 m below the water surface as shown in Fig . 5. Find the total hydrostatic force acting on one side of the plate and the vertical depth of the centre of pressure below the water surface. 8

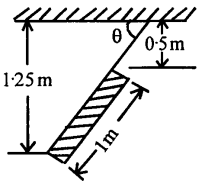


Fig. 5

(*d*) What are the instruments you can use to measure the flow rate of a fluid? 2

6. (*a*) Show that the energy of a fluid is a property. What are different modes in which energy may be stored in a system? 6

(*b*) A mass of 8 kg gas expands within a flexible container so that the $p-v$ relationship is of the form $pv^{1\cdot2}$ constant. The initial pressure is 1000 kPa and the initial volume is $1\,m^3$. The final pressure is 5 kPa. If the specific internal energy of the gas decreases by 40 kJ/kg, find the heat transfer in magnitude and direction. 8

(*c*) How does the current flowing through a resistor represent work transfer? Under what conditions is the work done equal to $\int_1^2 pdv$? 6

(*c*) parabolic path.
(*d*) curvilinear path.

(*v*) The time period of oscillation of a simple pendulum depends upon
(*a*) the mass of the suspended body.
(*b*) length of the pendulum.
(*c*) angular displacement of the pendulum.
(*d*) tension of the string.

(*vi*) The normal component of acceleration of a particle moving with a uniform speed of 4 m/s along a circular path of radius 20 cm is given by
(*a*) zero
(*b*) 800 m/s
(*c*) $5\ m/s^2$
(*d*) $80\ m/s^2$

(*vii*) The centre of gravity of a right circular soild cone of height h is at this distance from the apex along the axis.
(*a*) $h/3$
(*b*) $h/4$
(*c*) $(3/4)\,h$
(*d*) $(2/3)\,h$.

(*viii*) The centre of pressure in a fluid
(*a*) is always below the centroid of the submerged area.
(*b*) exists for any curved surface having single or double curvature.

(*c*) is independent of the orientation of the area.
(*d*) is the point on the submerged area at which the resultant hydrostatic force is supposed to act.

(*ix*) It is not an extensive property of a system :
(*a*) Volume
(*b*) Pressure
(*c*) Energy
(*d*) Entropy

(*x*) Heat supplied to a system at constant pressure increases its
(*a*) internal energy.
(*b*) volume.
(*c*) enthalpy.
(*d*) pressure.

(*B*) Write in brief (3-4 lines) about the following : 5 x 2

(*i*) Varignon's theorem

(*ii*) Mohr's circle of stresses

(*iii*) Viscous fluid flow

(*iv*) Clausius' theorem

(*v*) Otto cycle

W'11:3FN:AN205 (1405)

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Group A

1. (*a*) Three identical cylinders, each weighing W, are stacked as shown in Fig. 1, on smooth inclined surfaces, each inclined at an angle θ with the horizontal. Determine the smallest angle θ to prevent the stack from collapsing. 9

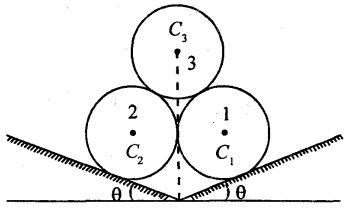

Fig. 1

(*b*) State the Coulomb's law of dry friction. 3

(*c*) A man wishes to climb a 5m long ladder placed at 60° on a horizontal surface ($\mu = 0{\cdot}3$) against a vertical wall ($\mu = 0{\cdot}2$). How far can he climb without the ladder slipping ? The man and the ladder weigh 800 N and 150 N, respectively. 8

2. (*a*) Define efficiency of a screw jack. 2

(*b*) A screw thread of a screw jack has a mean diameter of 10 cm and a pitch of 1·25 cm. The coefficient of friction between the screw and its nut-housing is 0·25. Determine the force *F* that must be applied at the end of a 50 cm lever arm to raise a mass of 5000 kg. Is the device self-locking ? Also, determine its efficiency ? 6

(*c*) A large balloon is rising up with a velocity of 9·81 m/s at an altitude of 39·2 m from the ground. At that instant, a stone of mass 5 kg is dropped from it. After how many seconds will the stone reach the ground ? 5

(*d*) Locate the centroid of the given composite area shown in Fig. 2 : 7

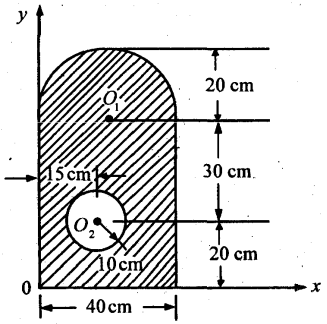

Fig. 2

3. (*a*) Determine the moments of inertia with respect to the centroidal axes of the wide-flange beam section shown in Fig. 3. 5

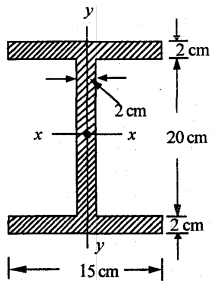

Fig. 3

(*b*) An elevator ascends with an upward acceleration of 1·2 m/s². At the instant when the upward speed is 2·4 m/s, a loose bolt drops from the ceiling of the elevator located 2·75 m from its floor. Calculate the (*i*) time of flight of the bolt from ceiling to floor of the elevator, (*ii*) displacement and the distance covered by the bolt during free fall relative to elevator shaft. 6

(*c*) A small motor of mass 20 kg is symmetrically mounted on four equal springs, each with a spring constant of 25 N/cm. Estimate the frequency and period of vibration of the motor. 3

(*d*) What is Mohr's circle ? What is its significance ? 6

4. (*a*) Draw the shear force and bending moment diagrams for the beam loaded as shown in Fig. 4. 12

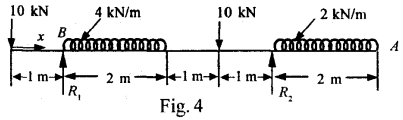

Fig. 4

(*b*) Calculate the diameter of the solid shaft required to transmit a torque of 4500 Nm. The twist of the shaft not to exceed 1° over a length of 2 m. The shear modulus G of the shaft material is 133 GN/m². Also, calculate the maximum shear stress in the shaft. 8

Group B

5. (*a*) The space between two square flat parallel plates is filled with oil. Each side of the plate is 60 cm. The thickness of the oil film is 12·5 mm. The upper plate, which moves at 2·5 m/s, requires a force of 98·1 N to maintain the speed. Determine the (*i*) dynamic viscosity of the oil in poise, and (*ii*) kinematic viscosity of oil in stokes, if the specific gravity of oil is 0·95. 6

(*b*) Calculate the capillary rise in a glass tube of 2·5 mm diameter when immersed vertically in (*i*) water, and (*ii*) mercury. Take surface tension $\sigma = 0{\cdot}0725$ N/m for water and $\sigma = 0{\cdot}52$ N/m for mercury in contact with air. The specific gravity of mercury is given as 13·6 and angle of contact = 130°. 4

(*c*) A circular opening, 3m diameter in a vertical side of a tank, is closed by a disc of 3 m diameter which can rotate about a horizontal diameter. Calculate the (*i*) force on the disc; and (*ii*) torque required to maintain the disc in equilibrium in vertical position when the head of water above the horizontal diameter is 4 m. 4

(*d*) The water is flowing through a pipe having diameters 20 cm and 10 cm at sections 1 and 2, respectively. The rate of flow through pipe is 35 litre/s. The section 1 is 6 m above datum and section 2 is 4 m above datum. If the pressure at section 1 is 39·24 N/cm², find the intensity of pressure at section 2. 6

6. (*a*) Define the following terms : 4 × 1

(*i*) Ideal gas

(*ii*) Constant volume specific heat

(*iii*) Enthalpy

(*iv*) Universal gas constant.

(*b*) For a reversible adiabatic process, prove that Pv^r = constant, where r is the ratio of specific heats. Show the process on P - v and T - s co-ordinates. 8

(*c*) A cylinder contains 0·45 m³ of a gas at 1 bar and 80° C. The gas is compressed to a volume of 0·13 m³, the final pressure being 5 bar. Determine the (*i*) mass of gas, (*ii*) index 'n' for compression, (*iii*) change in internal energy, (*iv*) heat transfer. Take $\gamma = 1{\cdot}4$, $R = 294{\cdot}2$ J/kg K. 8

7. (*a*) State the first law of thermodynamics for a closed system undergoing a cycle, and prove that energy is a property. 6

(*b*) Prove that the efficiency of air standard Otto cycle increases with increase in compression ratio. 6

(*c*) At the inlet to a certain nozzle, the enthalpy of fluid passing is 2800 kJ/kg, and the velocity is 50 m/s. At the discharge end, the enthalpy is 2600 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it. (*i*) Find the velocity at exit of the nozzle, (*ii*) If the inlet area is 900 cm² and the specific volume at inlet is 0·187 m³/kg, find the mass flow rate, and (*iii*) If the specific volume at the nozzle exit is 0·498 m³/kg, find the exit area of nozzle. 8

8. (*a*) Write the two statements of second law of thermodynamics. 4

(*b*) A Carnot engine operates between two reservoirs at temperatures T_1 °K and T_2 °K. The output of the heat engine is 0·6 times the heat rejected. Given that the difference in temperatures between source and sink is 200°C, calculate the (*i*) source temperature; (*ii*) sink temperature, and (*iii*) thermal efficiency. 5

(*c*) One kg of water at 0° C is brought into contact with a heat reservoir at 90° C. When the water has reached 90°C, find (*i*) entropy change of water, (*ii*) entropy change of heat reservoir, and (*iii*) entropy change of universe. 5

(*d*) An engine of 250 mm bore and 375 mm stroke works on Otto cycle. The clearance volume is 0·00263 m³. The initial pressure and temperature are 1 bar, 50°C. If the maximum pressure is 25 bar, find (*i*) efficiency, and (*ii*) pressure at the end of compression. 6

Group C

9. Choose the *correct* answer for the following : 10 × 2

(*i*) The centre of gravity of a hemisphere of radius *r* from its base measured along vertical radius is

(*a*) 4*r*/3
(*b*) 3*r*/2
(*c*) 3*r*/8
(*d*) 4*r*/7

(*ii*) A couple can be balanced by

(*a*) a force.
(*b*) a moment.
(*c*) a torque.
(*d*) an equal and opposite couple.

(*iii*) Thin cylinder vessel of diameter 100 mm wall thickness 2·5 mm is subjected to an internal water pressure of 1·5 N/mm². The maximum stress developed in cylinder wall is

(*a*) 15 N/mm²
(*b*) 30 N/mm²
(*c*) 60 N/mm²
(*d*) 120 N/mm²

(*iv*) The radius of Mohr's circle for two unlike principal stresses of magnitude *P* is

(*a*) *P*
(*b*) *P*/2
(*c*) *P*/4
(*d*) None of the above.

(*v*) Which one of the following devices is used to measure the velocity of a fluid in a pipe ?

(*a*) Venturimeter
(*b*) Pitot tube
(*c*) Orifice meter
(*d*) Manometer.

(*vi*) For a reversible adiabatic process, the change in entropy is

(*a*) zero.
(*b*) minimum.
(*c*) maximum.
(*d*) unity.

(*vii*) Which one of the following is the extensive property of a thermodynamic system ?

(*a*) Pressure
(*b*) Volume
(*c*) Temperature
(*d*) Density

(*viii*) In a isothermal process,

(*a*) volume remains constant.
(*b*) temperature increases gradually.
(*c*) change in internal energy is zero.
(*d*) pressure remains constant.

(*ix*) If two forces of magnitude P act at an angle θ, then the resultant force will be

(*a*) $2P \cos (\theta/2)$
(*b*) $2P \sin \theta$
(*c*) $2P \cos \theta$
(*d*) $P \cos 2\theta$

(*x*) For unstable equilibrium of submerged body,

(*a*) centre of buoyancy is below centre of gravity.
(*b*) centre of buoyancy is above centre of gravity.
(*c*) centre of buoyancy coincides with centre of gravity.
(*d*) None of the above.

S'12:5FN:AN205 (1405)

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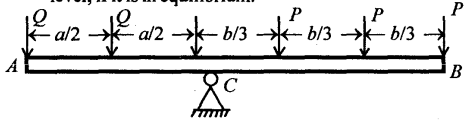
Group A

1. (*a*) A lever AB rests horizontally on a fulcrum at C such that $AC = a$ and $CB = b$. Two loads, each of magnitude Q, acting on the left of C, one at the free end A and the other midway between A and C. Three loads, each of magnitude P, acting on the right of C, one at the free end B, the second at a distance of $b/3$ on the left of B and the third at a distance of $b/3$ on the right of C. If $Q = 2P$ and the weight of the lever is negligible, determine the ratio $a : b$ of the arm of the lever, if it is in equilibrium. 7



(*b*) Explain Varignon's theorem. 3

(Turn Over)

(*c*) A uniform ladder AB of 7 m length rests against a vertical wall B with which it makes an angle of 45°, the coefficient of friction between the ladder and wall is 1/3 and that between the ladder and floor is 1/2. A man, whose weight is half of that of the ladder, ascends it. What will be the distance from A on the ladder when the ladder slips ? 10

2. (*a*) Find the centre of gravity of the E-section with respect to the point 0, as shown in Fig. 1. All dimensions are in mm. 7

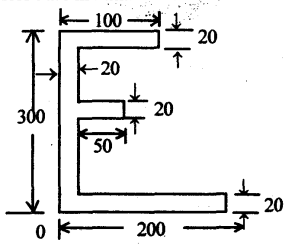


Fig. 1

(*b*) What do you mean by radius of gyration ? 3

(*c*) Find the moment of inertia of an I-section about its centroidal axes (Fig. 2) having top flange 60 mm × 10 mm, bottom flange 120 mm × 10 mm and web 100 mm × 10 mm. 10

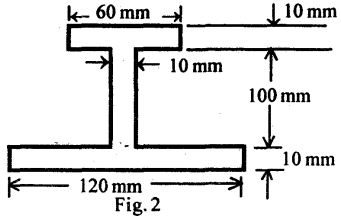


Fig. 2

3. (*a*) In a lifting machine, an effort of 98·2 N raised a load of 1000 N and an effort of 498·2 N raised a load of 6000 N. Find the law of the machine. What is the effort required to lift a load of 10,000 N ? Find the maximum mechanical advantage. 10

(*b*) Derive an expression for the time taken by a body projected vertically upwards with a velocity u to reach a height h. 4

(*c*) A stone, after falling from rest, breaks a glass pane and in breaking it looses 25% of its velocity. How far will it fall in the next second ? Take $g = 9{\cdot}81$ m/s². 6

4. (*a*) A ball is projected from the ground at an angle of 60° with the horizontal with a velocity of 40 m/s. Find the distance covered by the ball vertically and horizontally after 2 sec. 6

(*b*) Explain what you understand by strain energy. Show that the strain energy of a body per unit volume is $\sigma^2/2E$. 6

(*c*) Two elastic bars of the same material and length, one of circular section of diameter 120 mm and the other square of side 120 mm, absorb the same amount of strain energy delivered by axial forces. Compare the stress induced in two bars. 5

(*d*) What is meant by bending stress ? 3

Group B

5. (*a*) A 2 mm diameter glass tube is immersed in mercury. Estimate the depression, if the surface tension for mercury is 0·472 N/m and the contact angle is 125°. Take for Hg, $\rho = 13{\cdot}6 \times 10^3$ kg/m³. 5

(*b*) The bearing of an engine is 10 cm in diameter and 5 cm long. The engine runs at 3000 rpm. The clearance between the bearing and the shaft is 0·5 mm and the viscosity of the lubricating oil is 0·44 Ns/m². Assuming that the velocity in oil film varies linearly with the radius, calculate the power lost in the bearing. 8

(*c*) A submarine is cruising at a depth of 15 m below the sea surface. If the forward speed of the submarine is 16 km/h, calculate the pressure at the front stagnation point. Take density of seawater as 1026 kg/m³. 7

6. (*a*) What is displacement work ? Under what conditions is the work done equal to $\int pdV$? 4

(*b*) A mass of gas is compressed in a quasi-static process from 80 kPa, 0·1 m³ to 0·4 MPA, 0·03 m³. Assuming that the pressure and volume are related by pv^n = constant, find the work done by the gas system. 6

(*c*) A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During a cycle, the sum of all heat transfers is –170 kJ. The system completes 100 cycles/min. Complete the following table and compute the network output (in kW) : 10

Process	Q, kJ/min	W, kJ/min	ΔE, kJ/min
a - *b*	0	2170	——
b - *c*	21,000	0	——
c - *d*	–2100	——	– 36,600
d - *a*	——	——	——

7. (*a*) In a steady flow apparatus, 135 kJ of work is done per kg of fluid. The specific volume, pressure and velocity at inlet are 0·37 m³/kg, 600 kPa and 16 m/s. The inlet

is 32 m above the floor, and the discharge pipe is at the floor level. The discharge conditions are 0·62 m³/kg, 100 kPa and 270 m/s. The total heat loss between the inlet and exit is 9 kJ/kg. In flowing through the apparatus, does the specific internal energy increase or decrease, and by how much ? 10

(*b*) To produce net work in a cycle, a heat engine has to exchange heat with two thermal reservoirs. Explain. 3

(*c*) Explain why all spontaneous processes are irreversible. 3

(*d*) What is a heat pump ? Show that the COP of a heat pump is greater than the COP of a refrigerator by unity. 4

8. (*a*) Water flows through a turbine in which friction causes the water temperature to rise from 35 °C to 37 °C. If there is no heat transfer, how much does the entropy of the water change in passing through the turbine ? 5

(*b*) Why is an isentropic process not necessarily an adiabatic process ? 3

(*c*) What is a spark ignition engine ? What is the air standard cycle of such an engine ? Show that this efficiency depends only on the compression ratio. Why does the compression ratio of an SI engine get restricted ? 12

Group C

9. (A) Choose the *correct* answer for the following : 10 × 1

(*i*) The C.G. of a right circular solid cone of height *h* is at a distance of

(*a*) *h*/2

(*b*) $h/3$
(*c*) $h/4$
(*d*) $3/4\ h$

from the apex along the central axis.

(*ii*) The body which does not deform under the action of applied forces is known as a

(*a*) solid body.
(*b*) non-plastic body.
(*c*) rigid body.
(*d*) hard body.

(*iii*) The path of an object thrown into the space under gravity at a certain angle is called a

(*a*) projectile.
(*b*) trajectory.
(*c*) parabolic path.
(*d*) curvilinear path.

(*iv*) The normal component of acceleration of a particle moving with a uniform speed of 4 m/s along a circular path of radius 20 cm is given by

(*a*) zero.
(*b*) 800 m/s^2
(*c*) 5 m/s^2
(*d*) 80 m/s^2.

(*v*) The cyclic integral of following one is zero :

(*a*) Work transfer
(*b*) Heat transfer
(*c*) Temperature
(*d*) Latent heat.

(*vi*) The following one does not change during a throttling process :

(*a*) Enthalpy
(*b*) Entropy
(*c*) Specific volume
(*d*) Pressure.

(*vii*) When a system is in equilibrium, any conceivable change in entropy would be

(*a*) maximum.
(*b*) zero
(*c*) minimum.
(*d*) positive.

(*viii*) For an ideal gas, following one is a function of temperature only.

(*a*) Specific heat
(*b*) Internal energy
(*c*) Entropy
(*d*) Volume.

(*ix*) The efficiency of a reversible cycle depends upon the

(*a*) nature of the working substance.
(*b*) amount of the working substance.
(*c*) temperatures of the two reservoirs between which the cycle operates.
(*d*) type of cycle followed.

(*x*) A pitot tube is used to measure the

(*a*) state of the fluid.
(*b*) velocity of the fluid.
(*c*) density of the fluid.
(*d*) viscosity of the fluid.

(B) Write short notes on *any five* of the following : 5 × 2

(*i*) Quasi-static process
(*ii*) PMM2
(*iii*) Ideal fluid
(*iv*) Principal stress
(*v*) Centre of pressure
(*vi*) Bernoulli's equation
(*vii*) Carnot cycle
(*viii*) Poisson's ratio.

W'12: 5 FN: AN 205 (1405)

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Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks

Group A

1. (*a*) State and prove Lami's theorem. 4

(*b*) A machine weighing 5 kN is supported by two chains attached to some point on the machine. One chain goes to the hook in the ceiling and has an inclination of 45° with the horizontal. The other chain goes to the eye bolt in the wall and is inclined at 30° to the horizontal. Make calculations for the tension induced in the chain. 8

(*c*) Forces equal to P, $2P$, $3P$, and $4P$ act along the sides AB, BC, CD and DA of a square ABCD. Find the magnitude, direction and line of action of the resultant. 8

(*b*) $2\sqrt{2}\,P$

(*c*) $2\,P$

(*d*) $\sqrt{5}\,P$

(*v*) When a wire is stretched to double its length, the longitudinal strain produced in it is

(*a*) 0.5

(*b*) 1.0

(*c*) 1.5

(*d*) 2.0

(*vi*) A steel rod passes through a brass tube which is closed by thin rigid washers and fastened by acts screwed to the rod. Which will be the type of stress induced in the tube when the nut is tightened on the bolt ?

(*a*) Tensile

(*b*) Compressive

(*c*) Shear

(*d*) Bending

(*vii*) First law of thermodynamics refers to conservation of

(*a*) mass.

(*b*) momentum.

(*c*) energy.

(*d*) force.

(*viii*) For a closed system, the difference between heat added to and work done by the system is equal to

(*a*) enthalpy.

(*b*) internal energy.

(*c*) Gibbs function.

(*d*) flow work.

(*ix*) For practical petrol engine working on Otto cycle, the compression ratio usually lies in the range

(*a*) 3-5

(*b*) 6-8

(*c*) 10-15

(*d*) 16-22

(*x*) The compression ratio for a practical diesel engine usually lies in the range

(*a*) 3-5

(*b*) 6-8

(*c*) 10-15

(*d*) 16-22

2. (*a*) Where does the centre of gravity of the following section lies ? (*i*) Semi-circle, (*ii*) trapezium, (*iii*) hemisphere, (*iv*) triangle, and (*v*) right circular solid cone. 5

(*b*) State and prove the theorem of perpendicular axis as applied to moment of inertia. 5

(*c*) Find the moment of inertia of a hollow section shown in Fig.1 about an axis passing through it and centre of gravity or parallel to X-X axis. 10

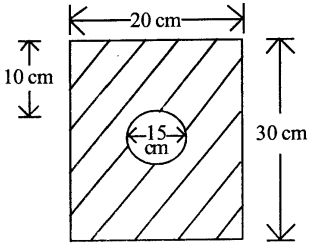

Fig. 1

3. (*a*) Define force, work, momentum and impulse. 4

(*b*) The relation $a = 2t$ defines the motion of a particle. It is given that $s = 1.2$ m and $v = 0.6$ m/s when $t = 1$ sec. Find s and v at $t = 4$ sec. 8

(*c*) A 150 kg scooterist is travelling with a speed of 36 kmph on a road that makes an angle of 30° with another road upon which a 60 kg cyclist is travelling at 8 kmph. When they approach the crossing, they collide and move as one mass. Determine the final velocity, both in magnitude and direction. 8

4. (*a*) State Hooke's law. Distinguish between limit of proportionality and elastic limit. 4

(*b*) A reinforced column 50 cm × 50 cm in section is reinforced with 4 steel bar of 2.5 cm diameter, one in each corner. The column is carrying a load of 200 tonnes. Find the stresses in the concrete and steel bar. Take E for steel $= 2.1 \times 10^6$ kg/cm^2 and E for concrete $= 0.14 \times 10^6$ kg/cm^2. 8

(*c*) A simply-supported beam of 4 m long is subjected to two point loads of 2 kN and 4 kN, each at distances of 1.5 m and 3 m from the left end. Draw S.F. and B.M. diagrams for the beam. 8

Group B

5. (*a*) Explain the terms 'viscosity' and 'surface tension'. 4

(*b*) Prove that the relationship between surface tension and pressure inside a droplet of liquid in excess of outside pressure is given by $p = 4\sigma/d$. 4

(*c*) Two large plane surfaces are 2.4 cm apart. The space between the surface is filled with glycerine. What is the force required to drag a very thin plate of surface area 0.5 m^2 between the two large plane surface at a speed of 0.6 m/s, if the (*i*) thin plate is in middle of the two plane surface, and (*ii*) thin plate is at a distance of 0.8 cm from one of the plane surface ? Take the dynamic viscosity of glycerine $= 8.10 \times 10^{-1}$ Ns/m^2. 12

6. (*a*) Derive an expression for total pressure and centre of pressure for a vertically immersed surface. 10

(*b*) A rectangular plane surface is 2 m wide and 3 m deep. It lies in vertical plane in water. Determine the total pressure and position of centre of pressure on the plane surface when its upper edge is horizontal

and (*i*) coincides with water surface, and (*ii*) 2.5 m below the free water surface. 10

7. (*a*) What is the essence of first law of thermodynamics ? Write expressions for the first law applied to (*i*) a cycle, and (*ii*) a process. 4

(*b*) Explain the perpetual motion machine of first kind. 4

(*c*) A perfect gas undergoes the following three separate and distinct processes to execute a cycle :

(*i*) Constant volume process during which 80 kJ of heat is supplied to the gas.

(*ii*) Constant pressure process during which 85 kJ of heat is lost to the surrounding and 20 kJ of work is done on it.

(*iii*) Adiabatic process which restores the gas back to its initial state.

Evaluate the work done during adiabatic process and the value of internal energy at all the state point, if initially its value is 95 kJ. 12

8. (*a*) State the limitations of first law of thermodynamics. 4

(*b*) State the Kelvin-Planck and Clausius statements of the second law of thermodynamics. 4

(*c*) Three Carnot heat engines are arranged is series. The first engine takes 4000 kJ of heat from a source at 2000 K and delivers 1800 kJ of work. The second and third engines deliver 1200 kJ and 500 kJ of work, respectively. Make calculations for the exhaust temperature of the second and third Carnot engine. 12

Group C

9. Choose the *correct* answer for the following : 10 × 2

(*i*) A real practical fluid possesses which one of the following:

(*a*) Viscosity

(*b*) Surface tension

(*c*) Compressibility

(*d*) Density

(*ii*) Which one of the following is an example of phenomenon of surface tension ?

(*a*) Rain drops

(*b*) Rise of sap in tree

(*c*) Break-up of liquid jet

(*d*) All of the three above.

(*iii*) Which one of the following is not a projective ?

(*a*) A ball thrown upwards.

(*b*) A stone thrown horizontally from the top of a tower.

(*c*) A rocket fired into space.

(*d*) A bullet fired from the gun.

(*iv*) Four forces P, $2P$, $3P$ and $4P$ act along the sides taken in order of a square. The resultant force is

(*a*) 0

S'13 : 5 FN : AN 205 (1405)

MECHANICAL SCIENCE

Time : *Three hours*

Maximum Marks : *100*

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Group A

1. (*a*) State the law of parallelogram of forces. 3

(*b*) Find the magnitude of two forces such that, when they act at right angle, their resultant is $\sqrt{10}$ N, but if they act at 60°, the resultant is $\sqrt{13}$ N. 7

(*c*) What are the characteristics of a couple ? 3

(*d*) A horizontal beam AB of 30 m long rests on two supports at its ends and carries concentrated loads of 3 kN, 4 kN and 5 kN at 4 m, 10 m and 14 m, respectively from the left hand support A. Find the supporting forces or the reactions at the two ends. Neglect the weight of the beam. 7

2. (*a*) Define centre of gravity and centroid of an area. 4

(*b*) Find the position of centre of gravity of a semi-circle of radius 15 cm. Deduce the formula used. 5

(*c*) State the theorem of parallel axes. 3

(*d*) Determine the moment of inertia of an inverted T-section of flange 100 mm × 10 mm and web 120 mm × 12 mm about both the centroidal axes (Fig. 1): 8

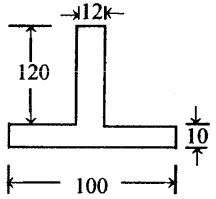

Fig. 1

3. (*a*) State the laws of static friction. If the angle of friction between two surfaces of contact is 15°, what is the value of coefficient friction? 3

(*b*) A block of stone, weighing 20 N, is resting on a plane which is inclined to the horizontal at an angle of 30°. A force, *P*, is acting on the block in direction parallel to the inclined plane. The coefficient of static friction between the block and the inclined plane is 0.2. Find the magnitude of *P* (*i*) when the block is on the point of sliding up the plane, and (*ii*) when the block is on the point of sliding down the plane (Fig.2): 7

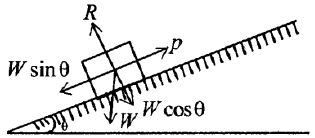

Fig. 2

(*c*) Derive an expression for the time taken by a body, projected upwards with a velocity *u* to reach a height *h*. 3

(*d*) A stone falling from rest breaks a glass pane and in breaking it looses 25% of its velocity. How far will it fall in the next second? Take $g = 9.81$ m/s^2. 7

4 (*a*) Define (*i*) Poisson ratio, (*ii*) modulus of rigidity, and (*iii*) strain energy. 3 × 2

(*b*) A bar 30 mm × 30 mm × 250 mm long is subjected to a pull of 90 kN in the direction of its length. The extension of the bar was found to be 0.125 mm, while the decrease in each lateral dimension is found to be 0.00375 mm. Find the Young's modulus, Poisson's ratio and modulus of rigidity for the material of the bar. 7

(*c*) Draw the shearing force and bending moment diagrams for a simply-supported beam carrying a (*i*) concentrated load, and (*ii*) uniformly distributed load. 5

(*d*) Show that the bending moment becomes maximum when the shearing force changes its sign. 2

Group B

5. (*a*) Write Bernoulli's equation and describe the various terms in it. For what kind of flow is the equation valid? 5

(*b*) A conical tube is fixed vertically with its smaller end upwards and it forms a part of pipeline. The velocity at the smaller end is 4.5 m/s and at the larger end it is 1.5 m/s. The length of the conical tube is 1.5 m. The pressure at the upper (smaller) end is equivalent to a head of 10 m of water. Neglecting friction, determine the pressure at the lower end of the tube. 7

(*c*) What do you mean by capillary effect ? 2

(*d*) Estimate the rise of water (P = 1000 kg/m^3) in a capillary tube of 2 mm diameter at 20 °C, assuming that the density of air is negligible and the surface tension is 0.0728 N/m. 6

6. (*a*) Explain the difference between energy in transit and energy in storage. What is the energy per unit mass for a (*i*) non-flow system, and (*ii*) a flow system ? 6

(*b*) A gas of 4 kg mass is contained within a piston-cylinder machine. The gas undergoes a process for which $pv^{1.5}$ = constant. The initial pressure is 3 bar and the initial volume is 0.1 m^3, and the final volume is 0.2 m^3. The internal energy of the gas decreases by 4.6 kJ/kg. Neglecting kinetic and potential energy changes, determine the net heat transfer for the process. 12

(*c*) What do you mean by PMM1 ? 2

7. (*a*) How does Bernoulli's equation compare with steady flow energy equation ? 4

(*b*) Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 290 K and a velocity of 6 m/s through an inlet of area 0.1 m^2. At exit, the pressure is 7 bar, the temperature is 450 K and the velocity is 2 m/s. Heat transfer from the compressor to the surroundings occurs at the rate of 180 kJ/min. Assuming that air behaves as an ideal gas with C_p = 1.005 and R = 0.287 kJ/kg/K, determine the power input to the compressor. 12

(*c*) What is the difference between a nozzle and a diffuser ? 4

8. (*a*) Give the Kelvin-Planck statement of the second law. Explain its significance. 4

(*b*) What is the difference between a refrigerator and a heat pump ? How do their COPs differ ? 5

(*c*) Explain the Carnot heat engine cycle. Does the nature of its working fluid have any effect on its efficiency ? 5

(*d*) A reversible power cycle operates between a reservoir at temperature T and a lower temperature reservoir at 200 K. At steady state, the cycle develops 40 kW of power while rejecting 1000 kJ/min by heat transfer to the cold reservoir. Determine the value of T. 6

Group C

9. (A) Choose the *correct* answer for the following : 10 × 1

(*i*) The path of an object thrown into the space under gravity at a certain angle is called

(*a*) projectile.

(*b*) trajectory.

(*c*) parabolic path.

(*d*) curvilinear path.

(*ii*) A flywheel, which makes 300 rpm about its centroidal axis, has angular velocity equal to

(*a*) 10π rad/s.

(*b*) $(5\pi/2)$ rad/s.

(*c*) $(2\pi/5)$ rad/s.

(*d*) 300π rad/s.

(*iii*) The normal component of acceleration of a particle moving with a uniform speed of 4 m/s along a circular path of radius 20 cm is given by

(*a*) zero.

(*b*) 800 m/s^2.

(*c*) 5 m/s^2.

(*d*) 80 m/s^2.

(*iv*) The body which does not deform under the action of applied forces is known as

(*a*) solid body.

(*b*) non-plastic body.

(*c*) rigid body.

(*d*) hard body.

(*v*) 'If three forces acting at a point are in equilibrium, each force is proportional to the sine of the angle between other two forces.' This is the statement according to

(*a*) Varignon's theorem

(*b*) Lami's theorem

(*c*) Triangular theorem

(*d*) Co-planar force diagram.

(*vi*) A pitot tube is used for measuring

(*a*) state of the fluid.

(*b*) velocity of fluid.

(*c*) density of fluid.

(*d*) viscosity of fluid.

(*vii*) Dynamic viscosity has the dimension of

(*a*) MLT^{-2}

(*b*) $ML^{-1}T^{-1}$

(*c*) $ML^{-1}T^{-2}$

(*d*) $M^{-1}L^{-1}T^{-1}$

(*viii*) Heat transferred to a system at constant volume increases its

(*a*) enthalpy.

(*b*) internal energy.

(*c*) volume.

(*d*) pressure.

(*ix*) It is *not* an extensive property :

(*a*) Volume

(*b*) Pressure

(*c*) Energy

(*d*) Entropy

(*x*) The cyclic integral of this is zero

(*a*) Work transfer

(*b*) Heat transfer

(*c*) Temperature

(*d*) Latent heat

(B) Explain *any five* of the following in brief : 5 × 2

(*i*) Varignon's theorem

(*ii*) Polar moment of inertia

(*iii*) Laws of lifting machine

(*iv*) Simple harmonic motion

(*v*) Reynolds number

(*vi*) Energy reservoir

(*vii*) Bulk modulus of elasticity

(*viii*) Ultimate stress.

W'13 : 5 FN : AN 205 (1405)

MECHANICAL SCIENCE

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Group A

1. (*a*) What is free body diagram ? Explain with an example. 6

(*b*) Determine the horizontal force, F, to be applied to the block weighing 1500 N to hold it in position on a smooth inclined plane AB which makes an angle of 30° with the horizontal as shown in Fig. 1 : 6

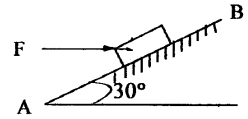

Fig. 1

(*c*) Two identical cylinders, each weighing 500 N, are placed in a trough as shown in Fig. 2. Determine the reaction developed at contact points A, B, C and D.

Assume all points of contact are smooth. 8

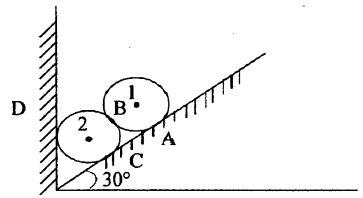

Fig. 2

2. (*a*) Define (*i*) angle of friction, (*ii*) angle of limiting friction, and (*iii*) angle of repose. 3 × 2

(*b*) Block A weighing 1000 N rests over block B which weighs 2000 N as shown in Fig. 3. Block A is tied to wall with a horizontal string. If the coefficient of friction between blocks A and B is 0.25 and between B and floor is 1/3, what should be the value of P to move the block B, if P is horizontal ? 6

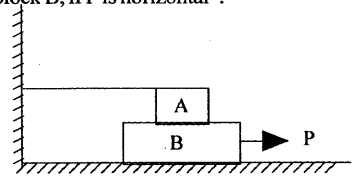

Fig. 3

(*c*) A ladder of length 4 m, weighing 200 N, is placed against a vertical wall as shown in Fig. 4. The coefficient of friction between the wall and ladder is 0.2 and that between the floor and the ladder is 0.3. In addition to self-weight, the ladder has to support a man weighing 600 N at a distance of 3 m from A. Calculate the minimum horizontal force to be applied at A to prevent slipping. 8

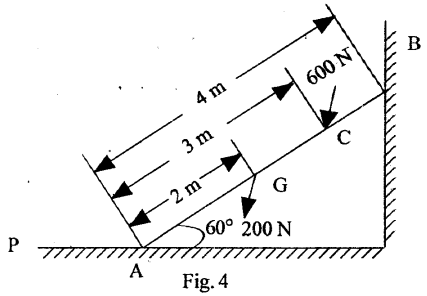

Fig. 4

3. (*a*) Define (*i*) area of moment of inertia, (*ii*) mass moment of inertia, and (*iii*) centroid. 3 × 2

(*b*) A screw jack raises a load of 40 kN. The screw is square threaded having three threads per 20 mm length and 40 mm in diameter. Calculate the force required at the end of a lever 400 mm long measured from the axis of the screw, if the coefficient of friction between screw and nut is 0.12. 7

(*c*) Find the centroid of the unequal angle 200 mm × 150 mm × 12 mm shown in Fig. 5. 7

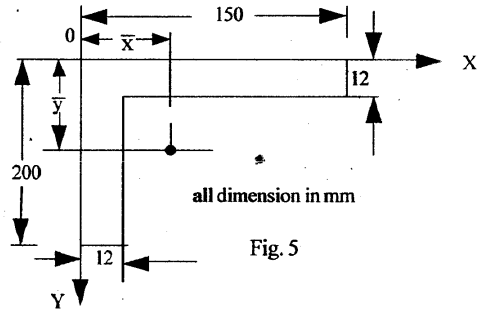

Fig. 5

4. (*a*) A projectile is aimed at a target on the horizontal plane and falls 12 m short when the angle of projection is 15°, while it overshoots by 24 m when the angle is 45°. Find the angle of projection to hit the target. 6

(*b*) Draw the stress (σ)-strain (ε) curve for steel. Show all the salient points. Explain how do you get the value of Young's modulus (E). 6

(*c*) A specimen of steel, 20 mm diameter with a gauge length of 200 mm, was tested to failure. It undergoes an extension of 0.20 mm under a load of 60 kN. Load at elastic limit is 120 kN. The maximum load is 180 kN. The breaking load is 160 kN. Total extension is 50 mm and the diameter at fracture is 16 mm. Find (*i*) stress at elastic limit, (*ii*) Young's modulus, (*iii*) percentage elongation, and (*iv*) percentage reduction in area. 4 × 2

Group B

5. (*a*) State Newton's law of viscosity. 2

(*b*) Define (*i*) ideal fluid, (*ii*) real fluid, (*iii*) Newtonian fluid, and (*iv*) non-Newtonian fluid. 4 × 1

(*c*) A flat plate of area 1.5×10^6 mm^2 is pulled with a speed of 0.4 m/s relative to another plate located at a distance of 0.15 mm from it. Find the force and power required to maintain this speed, if the fluid separating them is having viscosity as 1 poise. 6

(*d*) A rectangular plane surface is 2 m wide and 3 m deep. It lies in a vertical plane in water. Determine the total pressure and position of centre of pressure on the plane surface when its upper edge is horizontal and (*i*) coincides with water surface, and (*ii*) 2.5 m below the free water surface. 4 + 4

6. (*a*) Define the following terms: 4 × 1

(*i*) Thermodynamic system

(*ii*) Thermodynamic properties

(*iii*) Constant volume specific heat

(*iv*) Ideal gas

(*b*) For a reversible adiabatic process, prove that pv^γ = constant, where γ = ratio of specific heats. Represent the process on P-V and T-s planes. 8

(*c*) Air, initially at a pressure of 100 kPa and a volume of 3.1 m^3, is contained in a piston cylinder arrangement. It undergoes the following processes in a sequence to complete a cycle: (*i*) Adiabatic compression to a volume to 0.18 m^3, (*ii*) constant pressure heat addition until volume doubles, (*iii*) adiabatic expansion to its initial volume, and (*iv*) constant volume heat rejection till it reaches the initial pressure and volume. Show the cycle on P-V diagram and calculate the net work transfer during the cycle. Assume $\gamma = 1.4$ for air. 8

7. (*a*) State the first law of thermodynamics for a closed system undergoing a cycle and prove that energy is a property of the system. 8

(*b*) Write two statements of second law of thermodynamics. 4

(*c*) Air flows steadily at the rate of 0.5 kg/s through an air compressor, entering at 7 m/s velocity, 100 kPa pressure and 0.95 m^3/kg volume, and leaving at 5 m/s, 700 kPa and 0.19 m^3/kg, respectively. The internal energy of air leaving is 90 kJ/kg greater than that of the air entering. Cooling water in the compressor jackets absorbs heat from the air at the rate of 58 kW. Determine (*i*) work input to the air (in kW), and (*ii*) ratio of inlet and outlet pipe diameters. 4 + 4

8. (*a*) Prove that air standard efficiency of ideal Otto cycle always increases with increase in compression ratio. 7

(*b*) Distinguish between the principle of operation of SI and CI engines. 6

(*c*) A reversible heat engine operates between two reservoirs at temperatures of 600 °C and 40 °C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 40 °C and – 20 °C. The heat transfer to the engine is 2000 kJ and the net work output of the combined engine refrigerator plant is 360 kJ. Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40 °C. 7

Group C

9. Choose the *correct* answer for the following : 10 × 2

(*i*) In a simple harmonic motion, the line of oscillation is given by

(*a*) $T = 2\pi/\omega$

(*b*) $T = 2\pi\omega$

(*c*) $T = 2\pi/\omega^2$

(*d*) $T = 2\omega/\pi$

(*ii*) The radius of Mohr's circle for two unlike principal stresses of magnitude P is

(*a*) P

(*b*) P/2

(*c*) P/4

(*d*) None of the three above.

(*iii*) Maximum bending moment occurs when

(*a*) shear force is maximum.

(*b*) shear force is minimum.

(*c*) shear force changes sign.

(*d*) deflection is zero.

(*iv*) A couple can be balanced by

(*a*) a force.

(*b*) a moment.

(*c*) a torque.

(*d*) an equal and opposite couple.

(*v*) Work done in a free expansion process is

(*a*) zero.

(*b*) minimum.

(*c*) maximum.

(*d*) negative.

(*vi*) The centre of gravity of a hemisphere of radius, r from its base measured along vertical radius is

(*a*) $4r/3\pi$

(*b*) $3r/2$

(*c*) $3r/8$

(*d*) $4r/7$

(*vii*) For a reversible adiabatic process, the change in entropy is

(*a*) zero.

(*b*) minimum.

(*c*) maximum.

(*d*) unity.

(*viii*) Which one of the following is the extensive property of a thermodynamic system ?

(*a*) Pressure
(*b*) Volume
(*c*) Temperature
(*d*) Density

(*ix*) Viscosity of gases

(*a*) decreases with the increase of temperature.
(*b*) increases with the increase of temperature.
(*c*) remains same with the increase of temperature.
(*d*) None of the three above.

(*x*) Which one of the following device is used to measure velocity of a fluid in a pipe ?

(*a*) Venturimeter
(*b*) Pitot tube
(*c*) Orifice meter
(*d*) Manometer

S'14 : 5 FN : AN 205 (1405)

MECHANICAL SCIENCE

Time : *Three hours*

Maximum Marks : *100*

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Group A

1. (*a*) Define Young's modulus of elasticity (E), modulus of rigidity (G) and bulk/volume modulus of elasticity (K). Establish the relationship among them. The symbols have their usual meaning. 6

(*b*) Draw SFD and BMD for the beam shown in Fig. 1: 6

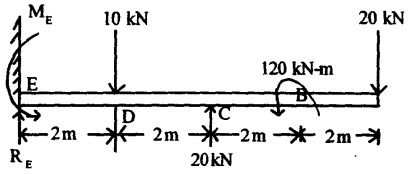


Fig. 1

(*c*) A steel shaft is to be manufactured either as a solid rod or as a circular tube. The shaft is required to

transmit a torque of 1200 Nm. The allowable shear stress for the shafts is 40 MPa and angle of twist permitted is 0.75°/m. The shear modulus of elasticity of the shaft material is 78 GPa. Determine the (*i*) required diameter of the solid shaft, (*ii*) required outer diameter of the hollow shaft, if the thickness of the shaft is specified as one-tenth of the outer diameter, and (*iii*) ratio of weights of the hollow and solid shaft. 3 + 3 + 2

2. (*a*) A 6 cm × 4 cm × 3 cm block (Fig. 2) carries normal axial loads (*i*) 120 kN (tension) on 4 cm × 3 cm face, (*ii*) 240 kN (compressive) on 4 cm × 6 cm face and (*iii*) 180 kN (tension) on 6 cm × 3 cm face. Poisson's ratio $\upsilon = 0.3$ and $E = 2\times10^5$ N/mm^2. Evaluate the strains in three directions and hence the change in volume. 10

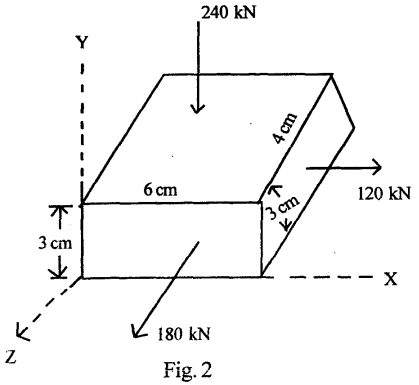


Fig. 2

(*b*) The intensity of resultant stress on a plane AB (Fig. 3) at a point in a material under stress is 80 MN/m^2 (tensile) inclined at 30° to normal to that plane. The normal component of stress on another plane BC at right angles to plane AB is 60 MN/m^2. Determine the (*i*) resultant stress on the plane BC, (*ii*) principal stresses and the principal planes and (*iii*) maximum shear stress and its plane. Solve analytically as well as graphically. 5 + 5

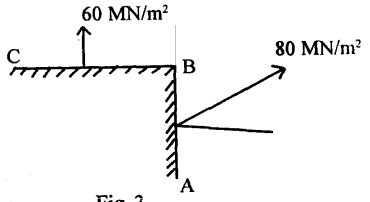


Fig. 3

3. (*a*) State and prove the perpendicular axis theorem. 4

(*b*) Using the method of virtual work, determine the force in the top member of the truss shown in Fig. 4. The triangles are equilateral. 4

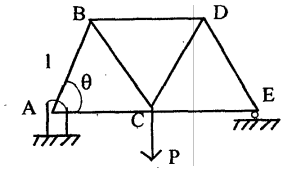


Fig. 4

(*c*) Two blocks A and B are connected to each other by a rope which passes over a fixed drum. Find the least value of the force, P, that will just start the system of blocks shown in Fig. 5 moving to the right. Weight of the blocks A and B are 3 kN and 5 kN, respectively. The coefficient of friction under each block and between rope and fixed drum is 0.20. 9

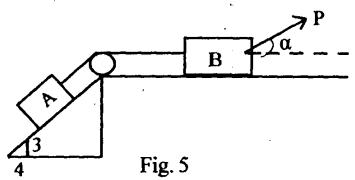


Fig. 5

(*d*) State equilibrium conditions for bodies under coplanar force. What will happen if these conditions are not satisfied ? 3

4. (*a*) The rectilinear motion of a particle is governed by $a = -8\,S^{-2}$, where a is in m/s² and S is in meter. When $t = 1$ sec, $S = 4$ m and $V = 2$ m/s, determine the acceleration of the particle at $t = 4$ sec. 6

(*b*) What is dynamic equilibrium ? State the principle of work and energy. 3

(*c*) A block (Fig. 6) weighing 2 kN, rests on a horizontal surface for which $u_k = 0.20$. This block is pulled by a force of 1 kN acting at an angle 30° to the horizontal. Find the velocity of the block after it moves 20 m starting from rest. If the force of 1 kN is removed, how far it will move ? 8

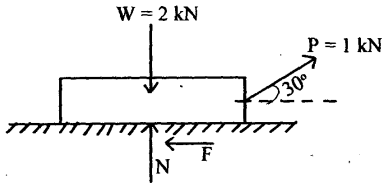


Fig. 6

(*d*) Find an expression for the work done of a rotating body when a torque, T, is acting on the body. 3

Group B

5. (*a*) Enunciate Newton's law of viscosity and distinguish between Newtonian and non-Newtonian fluids. 4

(*b*) A metallic body floats at the interface of mercury (specific gravity = 13.6) and water in such a way that 40% of its volume is submerged in mercury and 60% in water. Find the density of the metallic body. 4

(*c*) For the velocity field given by $V = 10xy\ i - 5y^2 j$, find, at point $P(2, 3)$, the (*i*) absolute velocity, (*ii*) absolute acceleration, (*iii*) angular velocity and (*iv*) value of stream function, if the streamline passing through the origin is assigned $\psi = 0$. 4 × 2

(*d*) Cite two examples of unsteady and non-uniform flow. How can the unsteady flow be transferred to steady flow ? 4

6. (*a*) The work associated with boundary movement (expansion/compression work) is given by $\int P.\,dv$. Is there a situation, where $W \neq \int P.\,dv$? 4

(*b*) Find the minimum apex angle of right circular solid cone of a material with specific gravity 0.8 so that it can float in stable equilibrium in fresh water with its axis vertical and the vertex downwards. 7

(*c*) Prove that violation of the Kelvin-Planck statement leads to violation of Clausius statement of the second law of thermodynamics. 5

(*d*) Find the horizontal and vertical components of water pressure acting on the face of a tainter gate of 90° sector of radius 4 m as shown in Fig. 7. Take width of gate as unity. 4

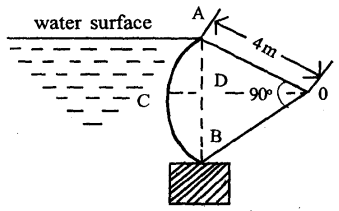


Fig. 7

7. (*a*) Explain the terms : state, path, process and cycle. 4 × 1

(*b*) Explain the physical significance of two constants that appear in the van der Waals' equation of state. 4

(*c*) An electric current of 10 A is maintained for 1 sec in a resistor of 25 Ω while the temperature of the resistor is maintained at 27 °C. Determine the (*i*) entropy change of the resistor, (*ii*) entropy change of the universe.

If same current is maintained for the same resistor but now thermally insulated, whose initial temperature is 27 °C, assuming the resistor has a mass of 0.01 kg and a specific heat of 0.84 kJ/kg.k, find the (*i*) entropy change of the registor and (*ii*) entropy change of the universe. 3 × 4

8. (*a*) What is a quasi-static process ? What are its characteristic features ? 3

(*b*) Explain reversible and irreversible process and state the conditions for a process to be reversible. 4

(*c*) Explain, with suitable sketches, the working of a four-stroke spark ignition engine. 5

(*d*) An amount of a perfect gas has initial conditions of volume 1 m^3, pressure 1 bar and temperature 18 °C. It undergoes ideal diesel cycle operations, the pressure after isentropic compression being 50 bar and the volume after pressure expansion being 0.1 m^3. Calculate the temperatures at the major points of the cycle and evaluate the thermal efficiency of the cycle. Assume $\gamma = 1.4$ for the gas. 8

Group C

9. Choose the *correct* answer for the following : 10 × 2

(*i*) The equation of a projectile is $y = \sqrt{3}\,x - (1/2)\,g\,x^2$. The angle of projection is given by

(*a*) $\tan\theta = 1/\sqrt{3}$ (*b*) $\tan\theta = \sqrt{3}$

(*c*) 60° (*d*) zero

(*ii*) A couple consists of two

(*a*) unlike parallel forces of different magnitude.

(*b*) like parallel forces of different magnitude.

(*c*) like parallel forces of same magnitude.

(*d*) unlike parallel forces of same magnitude.

(*iii*) A rigid body is in equilibrium under the action of three forces. It implies that the force must

(*a*) be coplanar.

(*b*) be concurrent.

(*c*) either concurrent or coplanar.

(*d*) pass through the centre of mass.

(*iv*) A free body diagram is an isolated view of a body which shows only the

(*a*) external forces exerted on it.
(*b*) internal forces.
(*c*) both (*a*) and (*b*) above.
(*d*) None of the three above.

(*v*) If a ladder is not in equilibrium against a smooth vertical wall, then it can be made in equilibrium by

(*a*) decreasing length of the ladder.
(*b*) increasing length of the ladder.
(*c*) increasing angle of inclination.
(*d*) decreasing angle of inclination.

(*vi*) The unit of rate of strain in a fluid at a point is

(*a*) m (*b*) m/s (*c*) rad/s (*d*) nil

(*vii*) The pressure at a point in a fluid is not equal in all directions, if

(*a*) the fluid is at rest.
(*b*) there are shear stresses.
(*c*) the fluid is accelerated.
(*d*) the fluid is rotated at a constant speed.

8.

(*viii*) The point through which the resultant hydrostatic force acts is called

(*a*) metacentre.
(*b*) centre of pressure.
(*c*) centre of buoyancy.
(*d*) centre of gravity.

(*ix*) Normal acceleration in fluid-flow situations exists only when the

(*a*) streamlines are straight and parallel.
(*b*) flow is unsteady.
(*c*) flow is irrotational.
(*d*) streamlines are curved.

(*x*) The buoyant force on a floating body is a force

(*a*) due to gravity and acts downwards.
(*b*) due to volume of liquid displaced by the body and acts vertically upwards.
(*c*) equal to the submerged weight of the body and acts vertically upwards.
(*d*) which acts horizontally on the vertical projection of the body.

W'14 : 5 FN : AN 205 (1405)

MECHANICAL SCIENCE

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) State the principle of virtual work and derive a relationship between F_x and F_y using it for four weightless bars of length a are hinged together at their junctions forming the shape of a rhombus as shown in Fig. 1 : 2 + 4

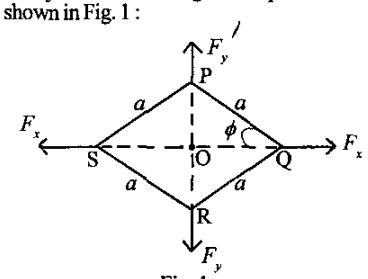


Fig. 1

(*b*) Determine the second moment of area of a semi-circle of radius R about (*i*) x-axis, y-axis, z-axis and about (*ii*) centroid x-axis. 6

(*c*) A smooth circular cylinder of weight, W, and radius, r, is supported by two semi-circular cylinders each of the same radius, r, and weight $W/2$ as shown in Fig. 2. If the coefficient of static friction between the flat faces of the semi-circular cylinders and the horizontal plane on which they rest is $\mu = 0.5$ and the friction between the interfaces of cylinders are neglected, determine the maximum distance, b, between the centres B and C for which the equilibrium will be possible without the middle cylinder touching the horizontal plane. 8

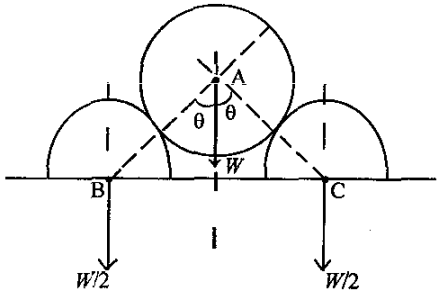


Fig. 2

2. (*a*) The acceleration of a body starting from rest moving along a straight line follows the law $a = t/30 + 2/3$, where a is in m/s^2 and t in sec. Obtain the velocity and displacement at $t = 10$ s. 4

(*b*) Derive the basic equation of motion of a spring-mass system vibrating in the absence of any forcing function. 4

(*c*) A solid cylinder of weight 673 kg and radius 37 cm is pushed with a constant force $F = 777$ N so that it rolls without slip on a rough track having $\mu = 0.31$ as shown in Fig. 3. To move starting from rest, how much distance will the cylinder take to attain a velocity of 7.7 m/s ? Take $\alpha = 27°$. 8

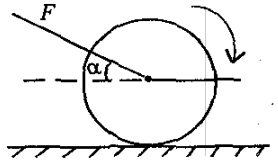


Fig. 3

(*d*) The coefficient of friction between the mastic asphalt pavement on the tyres of a truck is found to be 0.2 g. At what maximum constant speed, the truck can move around a curve on the level path without skidding ? Consider the radius of curvature as 350 m. 4

3. (*a*) Derive the expressions, from first principles, for circumferential and longitudinal stresses in a thin cylinder subjected to internal pressure. 4

(*b*) At a point in a piece of elastic material, there are three mutually perpendicular planes on which the stresses are as follows : Tensile stress 50 N/mm^2 and shear stress 40 N/mm^2 on one plane, compressive stress 35 N/mm^2 and complementary shear stress 40 N/mm^2 on the second plane. No stress on the third plane. Find analytically/using Mohr's circle method the (*i*) positions of planes on which there is no stress and (*ii*) principal stresses and positions of the planes on which they act. 6

(*c*) A bar of 25 mm diameter is subjected to a pull of 60 kN. The measured extension over a gauge

length of 250 mm is 0.15 mm and change in diameter is 0.004 mm. Calculate the modulus of elasticity and modulus of rigidity. 4

(*d*) A shaft is required to transmit 38 kW of power. At 240 rpm, the maximum torque may be twice the mean torque. The shear stress in the shaft should not exceed 40 N/mm^2 and twist 10 per metre length. Determine the diameter if the (*i*) shaft is solid and (*ii*) shaft is hollow and external diameter is 1.5 times the internal diameter. Modulus of rigidity = 80 GPa. 6

4. (*a*) Derive relations between bending moment, shear force and rate of loading for beams. Draw bending moment and shear force diagrams for a beam as shown in Fig. 4 : 8

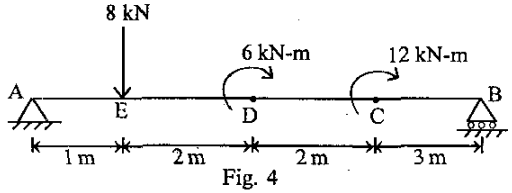


Fig. 4

(*b*) Establish the expression for the moment of a force about a line. 4

(*c*) Determine the induced axial force in the bottom member DC of the load truss shown in Fig. 5 : 8

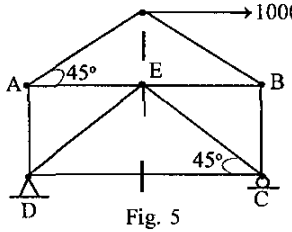


Fig. 5

Group B

5. (*a*) Derive an expression for the meta-centric height of a floating body. 4

(*b*) The space between two square flat parallel plates is filled with oil. Each side of the plate is 60 cm. The thickness of oil film is 12.5 mm. The upper plate, which moves at 2.5 m/sec, requires a force of 98.1 N to maintain the speed. Determine the (*i*) dynamic viscosity of the oil (in poise) and (*ii*) kinematic viscosity of the oil (in stoke), if the specific gravity of the oil is 0.95. 6

(*c*) The velocity vector in a fluid flow is given by

$$V = 4x^3\vec{i} - 10x^2y\,\vec{j} + 2t\,\vec{k}$$

Find the velocity and acceleration of a fluid particle at (2, 1, 3) at time $t = 1$ sec. 5

(*d*) Derive an expression for the depth of centre of pressure from free surface of liquid of an inclined plane surface submerged in the liquid. 5

6. (*a*) A cylinder, 3 m in diameter and 4 m long, retains water on one side. The cylinder is supported as shown in Fig. 6. Determine the horizontal reaction at A and vertical reaction at B. The cylinder weighs 196.2 kN. Neglect friction. 8

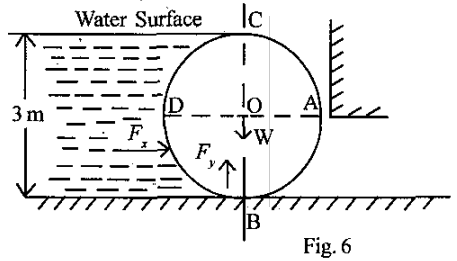


Fig. 6

(*b*) Differentiate between SI and CI engines. 4

(*c*) Distinguish between reversible and irreversible processes and give some examples of irreversible process. 4

(*d*) Express the law of conservation of mass for a control volume. 4

7. (*a*) For the same compression ratio and heat re-section, which cycle is the most efficient — otto or diesel ? Explain with P-V and T-s diagrams. 6

(*b*) Consider an air-standard diesel cycle with a compression ratio of 16. The conditions at the start of the compression stroke are 100 kPa and 37 °C. The entropy change of the air during the energy addition process is 1.2 kJ/kg-K. Determine the maximum temperature of the cycle, cut-off ratio, energy added as heat, and the thermal efficiency of the cycle. 8

(*c*) A reversible heat engine exchanges energy with three reservoirs at temperatures 1000 K, 800 K and 600 K, respectively. It receives 2000 kJ and 1200 kJ of energy from the reservoirs at 1000 K and 800 K, respectively. Calculate the energy exchanged with the third reservoir and the work output of the engine. 6

8. (*a*) A spherical balloon of 1 m diameter contains a gas at 150 kPa. The gas inside the balloon is heated until the pressure reaches 450 kPa. During the process of heating, the pressure of gas inside the balloon is proportional to cube of the diameter of the balloon. Determine the work done by the gas inside the balloon. 8

(*b*) Show that the first law of thermodynamics leads to the consequence that energy is a property of a thermodynamic system. 4

(*c*) Show that entropy is a property of a system. 4

(*d*) Explain the significance of Joule-Thomson co-efficient. 4

Group C

9. Choose the *correct* answer for the following : 10×2

(*i*) A force and a couple-moment directed along the force, equivalent to a system of forces, is called

(*a*) a momentum.

(*b*) a torque.

(*c*) a wrench.

(*d*) None of the three above.

(*ii*) A coplanar force and a coplanar couple acting on a rigid body

(*a*) balance each other.

(*b*) cannot balance each other.

(*c*) produce moment of a couple.

(*d*) produce force and couple.

(*iii*) In a frame structure, the nature of reactive force is in the nature of

(*a*) axial.

(*b*) bending.

(*c*) both axial and bending.

(*d*) tensile.

(*iv*) Which one of these coefficients has a unit ?

(*a*) Coefficient of static friction.

(*b*) Coefficient of kinetic friction.

(*c*) Coefficient of rolling friction.

(*d*) Coefficient of rolling resistance.

(*v*) In a simple screw jack, if φ is the inclination of the thread and φ_s, the limiting angle of static friction, the expression for maximum efficiency during hoisting load is

(*a*) $(1 - \sin \phi)/(1 + \sin \phi_s)$

(*b*) $1/(1 - \sin \phi_s)$

(*c*) $1/(1 + \sin \phi_s)$

(*d*) $(1 + \sin \phi_s)/(1 - \sin \phi_s)$

(*vi*) For a floating body, the buoyant force passes through the

(*a*) centre of gravity of the body.

(*b*) centre of gravity of submerged part of the body.

(*c*) metacentre of the body.

(*d*) centroid of the liquid displaced by the body.

(*vii*) Identify the process for which the two integrals — $\int V dp$ and $\int P dv$ — evaluate between any two given states give the same value :

(*a*) Isenthalpic

(*b*) Isothermal

(*c*) Isentropic

(*d*) Polytropic

(*viii*) A heat source of temperature T_1 transfers heat to a system at temperature T_2 ($T_1 > T_2$). Which one of the following statements is not true ?

(*a*) Δ s source decreases.

(*b*) Δ s system increases.

(*c*) (Δ s system + Δ s source) increases.

(*d*) (Δ s system + Δ s source) decreases.

(*ix*) Which one of the following equations is valid for a thermodynamic system undergoing a quasi-equilibrium process ?

(*a*) $\delta q = du + \delta w$

(*b*) $\delta q = du + p dv$

(*c*) $T. ds = du + \delta w$

(*d*) $T. ds = du + p.dv$

(*x*) Which one of the following laws of thermodynamics should be satisfied to ensure whether a system will undergo a process ?

(*a*) Zeroth law and first law.

(*b*) First law and second law.

(*c*) Second law and third law.

(*d*) Zeroth law and second law.

S'15: 5 FN: AN 205(1405)

MECHANICAL SCIENCE

Time : *Three hours*

Maximum Marks : *100*

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (*a, b, etc.*) *should be answered at one place.*

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper jstification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) State and prove the theorem of Varigon. 6

   (*b*) Develop the condition of maximum transmitted power in a flat belt drive. 6

   (*c*) Two smooth spheres, each of weight *w* and radius *r*, are in equilibrium in a horizontal channel of width *b* ($b < 4r$) and vertical sides as shown in Fig. 1. Find three reactions from the sides of channel which are all smooth. Also, find the force exerted by each sphere on the other. 8

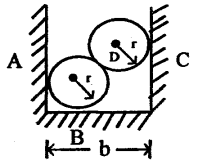


Fig. 1

(*Turn Over*)

2. (*a*) The acceleration of a particle along a straight line is given by the equation $a = 4 - (t^2/g)$. If the particle starts with velocity from a position $x = 0$, find (*i*) its velocity after 6 sec and (*ii*) distance travelled in 6 sec. 4

(*b*) A mass of weight 5 kg is connected with an inextensible cord wrapped around a cylinder, C, of weight 9 kg and radius 11 cm, and at rest position as shown in Fig. 2. If the weight is allowed to fall, determine its velocity after coming down a height of 7 cm. 6

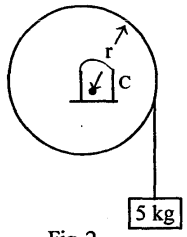


Fig. 2

(*c*) Derive the relationship between impulse and linear momentum. From this relation, how can you deduce the principle of conservation of linear momentum ? 6

(*d*) What is self-locking condition for a simple screw jack ? Is it advantageous ? 4

3. (*a*) A vibration system consists of a mass m and a spring of stiffness k. It has natural frequency of 12 Hz. The natural frequency decreases by 2 Hz when an extra mass of 2 kg is attached to m. Find k and mass. 4

(*b*) A pipe of 120 cm diameter is to carry water under a pressure of 200 N/cm^2. The longitudinal stress and the circumferential stress are not to exceed 3000 N/cm^2 and 4000 N/cm^2, respectively. Determine suitable thickness of the pipe, if the efficiencies of longitudinal and circumferential joints are 60% and 70%, respectively. 6

(*c*) Establish the relationship $E = 9KG/3K + G$, where E is the modulus of elasticity; G, the modulus of rigidity and K, the bulk modulus of elasticity. 6

(*d*) A solid MS shaft has to transmit 90 kW at 180 rev/min. The maximum torque exceeds the average by 30%. If the shearing stress is not to exceed 80 N/mm^2, determine a suitable diameter for the shaft. 4

4. (*a*) Two mutually perpendicular planes of an element of material are subjected to direct stresses of 10.5 MN/m^2 (tensile) and 3.5 MN/m^2 (compressive) and shear stress of 7 MN/m^2. Find graphically or otherwise the (*i*) magnitude and direction of principal stresses and (*ii*) magnitude of normal and shear stresses on a plane on which the shear stress is maximum. 4 + 4

(*b*) Determine the centroid of the area under the curve $x = ky^n$ (Fig. 3) 6

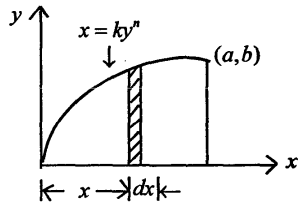


Fig. 3

(*c*) Using the method of section, find the forces in member CF of the given truss (Fig. 4): 6

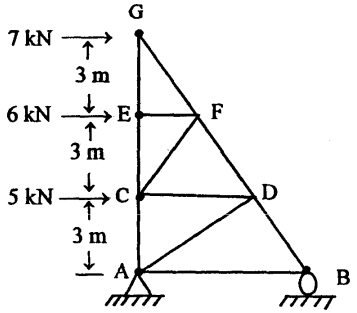


Fig. 4

Group B

5. (*a*) Differentiate between the following: 3 × 2

(*i*) Dynamic viscosity and kinematic viscosity

(*ii*) Centre of gravity and centre of buoyancy

(*iii*) Rotational and irrotational flows

(*b*) Derive an expression for the buoyant force acting on a submerged body with the help of hydrostatic equation. 4

(*c*) A square plate of size 1 m × 1 m and weighing 350 N slides down an inclined plane with a uniform velocity of 1.5 m/s. The inclined plane is laid on a slope of 5 vertical to 12 horizontal and has an oil film of 1 mm thickness (Fig.5) calculate the dynamic viscosity of oil. 5

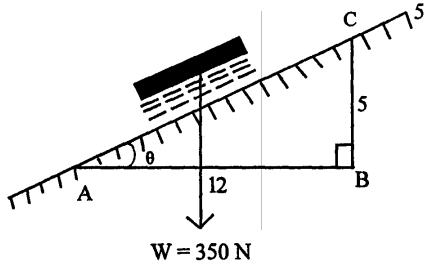


Fig. 5

(*d*) A 30 cm diameter pipe, conveying water, branches into two pipes of diameters 20 cm and 15 cm, respectively. If the average velocity in the 30 cm diameter pipe is 2.5 m/s, find the discharge in this pipe. Also, determine the velocity in 15 cm pipe, if the average velocity in 20 cm diameter pipe is 2 m/s. 5

6. (*a*) A circular plate of 3 m diameter is under water with its plane making an angle of 30° with the water surface (Fig. 6) If the top edge of the plate is 1 m below the water surface, find the force on one side of the plate and its location. 5

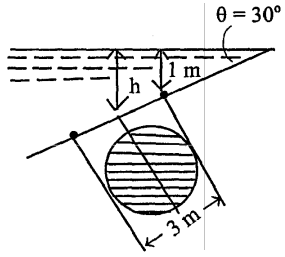


Fig. 6

(*b*) Describe, with a suitable sketch, the two-stroke cycle SI. How its indicator diagram differs from that of four-stroke cycle engine ? 5

(*c*) A certain engine at full load delivers 100 kW brake power. It requires 5 kW to rotate it without fuel at the same speed. Find its mechanical efficiency. Assuming that the mechanical losses remain constant, what will be the mechanical efficiency at (*i*) half load and (*ii*) quarter load ? 5

(*d*) What is the concept of continuum ? How will you define density and pressure using this concept ? 5

7. (*a*) What do you understand by path function and point function ? Show that heat is a path function and not a property. 6

(*b*) Show that the enthalpy of a fluid before throttling is equal to that after throttling. 4

(*c*) A fluid is confined in a cylinder by a spring-loaded frictionless piston so that the pressure in the fluid is a linear function of the volume ($p = a + bv$). The internal energy of the fluid is given by the following equation :

$$U = 34 + 3.15pV$$

where U is in kJ, p in kPa and V in cubic metre. If the fluid changes from an initial state of 170 kPa, 0.03 m^3 to a final state of 400 kPa, 0.06 m^3, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer. 6

(*d*) Calculate the power required by a compressor, if air flowing at the rate of 0.9 kg/s enters at 1.014 bar, 5 °C with a velocity of 61 m/s and leaves at 2.06 bar, 71 °C with a velocity of 122 m/s. Heat transferred from the air to the cooling water circulating around the compressor casing amounts to 18.6 kJ/kg of air. 4

8. (*a*) Establish the inequality of Clausius and show that entropy is a property. 6

(*b*) Show that the efficiency of all reversible heat engines operating between the same temperature levels is the same. 6

(*c*) A reversible heat engine is operating between two reservoirs at temperatures of 600 °C and 40 °C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 40 °C and −20 °C. The heat transfer to the heat engine is 2000 kJ and the net work output of the combined engine refrigerator plant is 360 kJ.

(*i*) Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40 °C; and 4

(*ii*) Reconsider (*i*) above, given that the efficiency of the heat engine and the COP of the refrigerator are each 40% of their maximum possible values. 4

Group C

9. Choose the *correct* answer for the following : 10 × 2

(*i*) Vertex angle of the cone of static friction is

(*a*) twice the angle of static friction.

(*b*) 90°

(*c*) half the angle of static friction.

(*d*) equal to angle of static friction.

(*ii*) Which of the following condition(s) is/are valid for the equilibrium of a rigid body subjected to three coplanar forces ?

(*a*) All forces are parallel.

(*b*) All forces are concurrent.

(*c*) At least two forces are concurrent.

(*d*) All the three above.

(*iii*) The magnitude of coefficient of restitution for a partially elastic impact is

(*a*) one

(*b*) any value from zero to one.

(*c*) zero

(*d*) None of the above.

(*iv*) The unit of elastic modulus is the same as those of

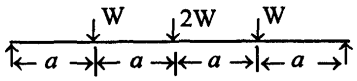
(*a*) stress, shear modulus and pressure.

(*b*) strain, shear modulus and force.

(*c*) shear modulus, stress and force.

(*d*) stress, strain and pressure.

(*v*) A simply-supported beam is loaded as shown below. The maximum shear force in the beam will be



(*a*) zero (*b*) W (*c*) 2 W (*d*) 4 W

(*vi*) When a system is in equilibrium, any conceivable change in entropy would be

(*a*) maximum. (*b*) zero.

(*c*) positive. (*d*) negative.

(*vii*) An isentropic process

(*a*) is always reversible.

(*b*) is always adiabatic.

(*c*) need not be adiabatic or reversible.

(*d*) is always frictionless.

(*viii*) Reversible steady flow work interaction is equal to

(*a*) $\int_1^2 p dv$ (*b*) $-\int_1^2 v dp$

(*c*) $u_1 - u_2$ (*d*) $p_1 v_1 - p_2 v_2$

(*ix*) Stroke of an IC engine equals

(*a*) half the crank radius.

(*b*) the crank radius.

(*c*) twice the crank radius.

(*d*) four times the crank radius.

(*x*) Newton's law of viscosity depends upon the

(*a*) stress and strain in a fluid.

(*b*) shear stress, pressure and velocity.

(*c*) shear stress and rate of strain.

(*d*) viscosity and shear stress.

W'15: 5 FN: AN 205 (1405)

MECHANICAL SCIENCE

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Discuss various coplanar force systems. 5

(*b*) Describe different methods of resolution of forces. 5

(*c*) State Varignon's theorem of moments. 5

(*d*) State properties of a couple. 5

2. (*a*) Explain centre of gravity and the centroid. 5

(*b*) Find the position of centroid of a quarter circle of radius *r*. 5

(*c*) State and prove the perpendicular axes theorem. 5

(*d*) Derive the expressions for radius of gyration of a circle with respect to its centroidal axes. 5

3. (*a*) Describe a screw jack. 5

(*b*) Prove that the maximum efficiency of screw jack, using square threaded screw, is given by $\eta_{max} = 1 - \sin\phi / 1 + \sin\phi$. 10

(*c*) State and explain the law of friction. 5

4. (*a*) Explain the Newton's laws of motion for linear motion. 5

(*b*) State and define the Alembert's principle for linear motion. 5

(*c*) Explain Mohr's circle for moment of inertia. 10

Group B

5. (*a*) Explain first law of thermodynamics. Also, discuss the corollary of the first law. 8

(*b*) Derive the expression of the energy equation of steady flow process. 6

(*c*) Explain the following terms: 3 × 2

(*i*) Adiabatic process

(*ii*) Polytropic process

(*iii*) Isothermal process

6. (*a*) Explain the second law of thermodynamics. 5

(*b*) Differentiate between internal energy and enthalpy. 5

(*c*) Explain entropy relation on the basis of the second law of thermodynamics. 10

7. (*a*) Explain dynamic and kinematic viscosity. 5

(*b*) Explain surface tension. 5

(*c*) Discuss in detail about non-newtonian fluids. 10

8. (*a*) Discuss the suitability of SI and CI engines for the vehicles on the basis of thermodynamic, operating variables and performance characteristics. 10

(*b*) Explain the principle of operation of four-stroke SI engines. 10

Group C

9. Answer the following in brief: 10 × 2

(*i*) Define piston rings.

(*ii*) What is the purpose of clearance volume in engines?

(*iii*) What do you understand by path function and point function?

(*iv*) Define rotational and irrotational flows.

(*v*) Differentiate between two-stroke and four-stroke engines.

(*vi*) What do you understand by carburetion and stoichiometric mixture?

(*vii*) Define Hooke's law.

(*viii*) Why is the engine lubrication necessary?

(*ix*) Define heat capacity.

(*x*) What is the function of crank shaft?

S'16: 5 FN: AN 205 (1405)

MECHANICAL SCIENCE

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Define the term 'free body diagram' and state the importance of drawing such a diagram. 4

(*b*) Establish the expression for the moment of a force about a line. 4

(*c*) A wooden block of weight 50 N rests on a horizontal plane. Determine the force required to just (*i*) pull it and (*ii*) push it. Take coefficient of friction $\mu = 0.4$ between the mating surfaces. Comment on the result. 8

(*d*) State the principle of virtual work. Explain it giving a suitable example. 4

2. (*a*) The acceleration of a body starting from rest moving

(Turn Over)

along a straight line follows the law

$$a = (t/30) + (2/3)$$

where a is in m/s^2 and t, in sec. Obtain the velocity and displacement at $t = 10$ s. 8

(*b*) The maximum horizontal range of a gun is Rm. Compute the firing angle to hit the enemy located at half distance of the maximum horizontal range. 4

(*c*) Two blocks, weighing 200 N and 300 N, are hung to the ends of a rope passing over an ideal pulley shown in Fig. 1. How much distance the blocks will move in increasing the velocity of the system from 2 m/s to 4 m/s ? How much is the tension in the string ? 8

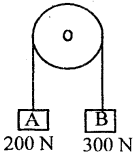


Fig. 1

3. (*a*) A 2 H.P. motor of weight 18.5 kg is mounted symmetrically on four identical springs, each of stiffness 200 g/mm. Determine the frequency and the time period of vibration of the motor. 6

(*b*) Derive an expression from first principles for circumferential and longitudinal stresses in a thin cylinder subjected to an internal pressure. 8

(*c*) Define moment of momentum (angular momentum) and establish a relationship between torque and angular momentum. 6

4. (*a*) Establish relationship among Young's modulus (E), modulus of rigidity (G) and bulk modulus (K). 8

(*b*) Draw the SF and BM diagrams for the beam as shown in Fig. 2 : 6

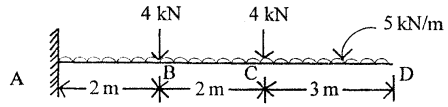


Fig. 2

(*c*) The outside diameter of a hollow shaft is twice its inside diameter. Find the ratio of its torque carrying capacity to that of solid shaft of the same material and the same outside diameter. 6

Group B

5. (*a*) Determine the viscosity of a liquid having kinematic viscosity 6 strokes and specific gravity 1.9. 4

(*b*) Explain briefly the working principle of Bourdon pressure gauge with a neat sketch. 6

(*c*) Explain the procedure of finding hydrostatic forces on curved surfaces. 4

(*d*) An open circular tank of 20 cm diameter and 100 cm long contains water up to a height of 60 cm. The tank is rotated about its vertical axis at 300 rpm. Find the depth of parabola formed at the free surface of water. 6

6. (*a*) Write the Euler's equation of motion along a stream line and integrate it to obtain Bernoulli's equation. State all assumptions made. 6

(*b*) Show that the internal energy is a property of the system. 6

(*c*) Air during a reversible process is compressed from initial process 12 kN/m^2 to 6 times the initial pressure. Due to the compression, volume of air decreases from initial volume 4 m^3 to 1.8 m^3. Calculate the (*i*) law of the process and (*ii*) work done in compressing the air. 4 + 4

7. (*a*) Show the equivalence of Clausius and Kelvin statements of second law of thermodynamics. 8

(*b*) For two cycles in series, the top cycle has an efficiency of 30% and the bottom cycle has an efficiency of 20%. Find the overall combined cycle efficiency. 6

(*c*) Define entropy and show that entropy is a property of system. 6

8. (*a*) Explain, with suitable sketches, the working of a four-stroke spark ignition engine. 6

(*b*) What is the difference between otto and diesel cycle ? Derive the formula for the efficiency of the diesel cycle. 8

(*c*) A certain engine at full load delivers 100 kW brake power. It requires 25 kW to rotate it without fuel at the same speed. Find its mechanical efficiency. Assuming that the mechanical losses remain constant, what will be the mechanical efficiency at (*i*) half load and (*ii*) quarter load ? 6

Group C

9. Answer the following in brief: 2 ×10

(*i*) Four forces P, 2P, 3P and 4P act along the sides

taken in order of a square. What will be the resultant force ?

(*ii*) Define radius of gyration.

(*iii*) Define angle of friction.

(*iv*) Find the second moment of a circular area about the diameter D.

(*v*) A bar of length L and of uniform cross-sectional area A is subjected to a pull P. If Young's modulus of elasticity of the bar material is E, find the strain energy stored in the bar.

(*vi*) Define metacentre.

(*vii*) Define circulation and vorticity.

(*viii*) State the first law of thermodynamics.

(*ix*) What is swept volume ?

(*x*) A new temperature scale (in degree) N is to be defined. The boiling and freezing points on this scale are 400 °N and 100 °N, respectively. What will be the reading on new scale corresponding to 60 °C ?

W'16: 5 FN: AN 205 (1405)

MECHANICAL SCIENCE

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** and ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answer may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) What is the difference between collinear and concurrent forces ? 4

(*b*) Define moment of a force about a point and show that the algebraic sum of the moments of two coplanar forces about a point is equal to the moment of their resultant about that point. 4

(*c*) Two forces are acting on a body and the body is in equilibrium. What conditions should be fulfilled by these two forces ? 4

(*d*) A body of weight 70 N is placed on a rough horizontal plane. To just move the body on the horizontal plane, a push of 20 N inclined at 20° to the horizontal plane is required. Find the coefficient of friction. 8

(Turn Over)

2. (*a*) Define the terms centroid and centre of gravity. Under what conditions these will coincide ? 4

(*b*) Define moment of inertia of a mass. How radius of gyration of a body is expressed in terms of its mass moment of inertia ? 4

(*c*) An air craft moving horizontally at a speed of 108 km/hr at an altitude of 1000 m towards a target on the ground releases a bomb which hits the target. Estimate the horizontal distance of the air-craft from the target when it released the bomb. Calculate also the direction and velocity with which the bomb hits the target. 12

3. (*a*) Explain the following : Hooke's law, Poisson's ratio, ultimate strength, modulus of rigidity. 4

(*b*) A horizontal girder which is freely supported at its ends and has a span of 9 m supports a uniformly distributed load of 20 kN/m run over the whole span and also two concentrated loads of 30 kN and 40 kN at points 6 m and 7.5 m respectively from the left support. Draw bending moment and shear force diagrams. 12

(*c*) Derive the following relationship between E,G and K.

$$E = \frac{9KG}{G+3K}$$ 4

4. (*a*) Derive an expression from first principles for circumferential and longitudinal stress in a thin cylinder subjected to an internal pressure. 6

(*b*) Describe the advantages of hollow shafts over solid shafts. Prove that a hollow shaft of the same weight and material as that of a solid shaft can resist more torque. 6

(*c*) Find the velocity and acceleration after 0.3 seconds from the extreme position of a body, moving with simple harmonic motion with an amplitude of 0.8 m and period of complete vibration of 1.6 seconds. 8

Group B

5. (*a*) Explain the following : Viscosity, compressibility, surface tension, non-newtonian fluids. 4

(*b*) A jet has a direct impact. In a plane moving in the direction of jet. Find the force of impact and the work done by the jet per second on the plate. 6

(*c*) A vertical pipe of diameter 100 mm is provided with a nozzle 300 mm long so as to direct a jet vertically. The pressure of water may be take to drop uniformly along the length of the nozzle. If the velocity of water in the pipe is 12 m/s and if the pressure at the base of the nozzle is 350 kP_a, find the (*i*) acceleration of water while passing through the nozzle (*ii*) jet velocity at outlet (*iii*) diameter of the nozzle outlet and (*iv*) vertical height to which the jet will rise. 10

6. (*a*) State and prove Euler's equation of motion. Obtain Bernoulli's equation from Euler's equation. State all the assumptions made. 8

(*b*) Define enthalpy. How is it related to internal energy ? 4

(*c*) How are the state parameters P,V and T related in a polytropic process ? What are the values of polytropic exponent for isobaric, isochoric, isothermal and adiabatic processes ? 8

7. (*a*) State the Kelvin-Planck and Clausius statements of the second law of thermodynamics and establish the equivalence between them. 8

(*b*) Define entropy and show that entropy is a property of system. 4

(*c*) A reversible heat engine is supplied 900 kJ of heat from a heat source at 500 K. The engine develops 300 kJ of network and rejects heat to two heat sinks at 400 K and 300 K. Determine the engine thermal efficiency and magnitude of heat interaction with each of the sink. 8

8. (*a*) Explain with neat sketches, the working of a four stroke diesel engine. 4

(*b*) Derive an expression for the air standard efficiency and mean effective pressure of an Otto cycle. State the assumptions made. 8

(*c*) The following data pertains to a compression ignition engine working on air standard diesel cycle :

Cylinder bore (dia.) = 15 cm
Stroke length = 25 cm
Clearance volume = 400 cm^3

Calculate the air standard efficiency of the engine if the fuel injection takes place at constant pressure for 5% of the stroke. How this efficiency value will be affected if the fuel supply continuous up to 8% of the stroke ? 8

Group C

9. Answer the following : 5 × 4

(*a*) Carnot cycle

(*b*) Law of conservation of energy

(*c*) Stress strain curve for ductile materials

(*d*) Laws of frictions

(*e*) Mohr's circle of stress