Code: A-03 **Subject: APPLIED MECHA**
Time: 3 Hours **Max. Marks: 1**

NOTE: There are 11 Questions in all.

- **Question 1 is compulsory and carries 16 marks. Answer to Q. 1. must be written in the space provided for it in the answer book supplied and nowhere else.**
- **Answer any THREE Questions each from Part I and Part II. Each of these questions carries 14 marks.**
- **Any required data not explicitly given, may be suitably assumed and stated.**

Q.1 Choose the correct or best alternative in the following: (2x8)

a. Three forces acting on a rigid body are in equilibrium. They must be

(A) coplanar. **(B)** concurrent .
(C)parallel. **(D)** collinear.

b. A perfect plane truss hinged at one end and simply supported at the other has 9 joints. The number of members, n in the truss would be

(A) 8. **(B)** 10.
(C) 12. **(D)** 15.

c. A body of weight W rests on a rough inclined plane with an angle θ to the horizontal and the angle of friction is φ. The total reaction of the plane on the body is inclined to the vertical at

(A) 0°. **(B)** θ.
(C) φ. **(D)** $\theta + \varphi$.

d. A flywheel of diameter 1m is rotating at an angular velocity of 2 radians/s and an angular acceleration of 3 radians/s^2. The acceleration of a point on the rim of the flywheel would be

(A) $0 \ m/s^2$. **(B)** $1.5 \ m/s^2$.
(C) $2 \ m/s^2$. **(D)** $2.5 \ m/s^2$.

e. A beam hinged at both ends is acted upon by a couple M at the centre. The maximum bending moment in the beam is

(A) 0. **(B)** M/2.
(C) M. **(D)** 2M.

f. The stiffness of a close-coiled spring is k. If the diameter of the spring wire were doubled, its stiffness k would be

(A) 2k. **(B)** 4k.
(C) 8k. **(D)** 16k.

g. The vacuum pressure in a vessel is p. If the atmospheric pressure is p_{atm} the absolute pressure in the vessel would be

(A) p_{atm}. **(B)** p.
(C) $p_{atm} - p$. **(D)** $p_{atm} + p$.

h. The runner vanes of a reaction turbine are made adjustable for

(A) reducing wear and tear of the runner.
(B) optimum efficiency at part loads.
(C) running at different speeds.
(D) operating at all temperature and pressure.

PART I
Answer any THREE Questions. Each question carries 14 marks.

Q.2 A light ladder 6 m long rests on a rough horizontal floor and against a smooth vertical wall at an angle $\alpha = 30^\circ$ to the wall. If the friction angle for the contact at the floor is 15°, find the maximum distance **d** along the ladder which a man of weight 800 N can climb before the ladder slips. Also determine the maximum angle 'α' so that the man can climb to the top of the ladder without slipping. **(14)**

Q.3 Draw the free body diagram for the whole frame shown in figure Q.3 and find the support reactions. Draw the free body diagrams for the member CD, member ABC and determine the force in member CD. **(14)**

Q.4 a. Derive the expression $I = \pi R^4 / 2$ for area moment of inertia of a circular area of radius R about an axis normal to the area through its centre. **(6)**

b. Determine the centroid of a thin disc of radius R with a hole of radius R/2 such that the centre of the hole and that of the disc are at a distance R/2. Also find its area moment of inertia about an axis normal to the disc through its centroid. **(8)**

Q.5 Three masses, A of 6 kg, B of 3 kg and C of 2 kg, connected by light inextensible strings passing over light frictionless pulleys are shown in figure Q.5. Determine their accelerations. Take acceleration due to gravity $g = 10 m/s^2$. **(14)**

Q.6 A steel rod of 5 m long is fixed at the top and must support a mass of 1000kg attached at its bottom without stretching more than 3 mm and not exceeding an allowable stress of 150 MPa. Neglect the mass of the rod. Take Young's modulus E = 210 GPa and acceleration due to gravity $g = 10 m/s^2$. Find the diameter of the rod to the nearest millimetre. Find the spring constant of the rod. If the load were pulled down and released so that the rod has free longitudinal vibrations, determine the frequency of vibrations. **(14)**

PART II

Answer any THREE Questions. Each question carries 14 marks.

Q.7 A light cantilever beam of length L is subjected to a uniformly distributed load 'w' per unit length, over a distance 'b' starting from the free end. Draw the S.F., B.M. diagrams and find the maximum values. Also find the maximum deflection. Take EI as the flexural rigidity. **(14)**

Q.8 a. Determine the maximum stress due to torsion in a closely coiled helical spring subjected to an axial pull P. Also derive an expression for its deflection. **(4)**

b. Calculate the ratio of torques transmitted by a solid and a hollow circular shafts of the same material, length and weight. **(10)**

Q.9 a. A cube of side 'b' floats with its sides vertical in water. If the metacentric height is zero, determine the specific gravity γ of the cube material. **(8)**

b. Show that the velocity components: $u = 2x - x^2y + y^3/3$ and $v = xy^2 - 2y + x^3/3$, represent a possible two dimensional incompressible irrotational flow. **(6)**

Q.10 a. Derive Euler's equation of motion for 2-D inviscid steady flow in a vertical plane. **(8)**

b. A conical draft tube attached to a Francis turbine has the inlet diameter 3 m and the outlet diameter 5 m. The velocity of the water at inlet is 5 m/s. The tail water level is 5 m below the entrance to the draft tube. If the friction losses in the draft tube are 0.1 m of water, find the pressure head at the entrance to the draft tube. **(6)**

Q.11 Derive an expression for the hydraulic efficiency of a Pelton wheel. Show that the efficiency is maximum when the bucket speed is half the jet speed. **(14)**

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Q.1 Choose the correct or best alternative in the following: (2x8)

a. A steel block is loaded by a tangential force on its top surface while the bottom surface is held rigidly. The deformation of the block is due to

(A) shear. **(B)** bending.
(C) Torsion. **(D)** shear and bending.

b. Specific speed of a Francis turbine ranges between

(A) 30 and 60. **(B)** 60 and 300.
(C) 300 and 600. **(D)** 600 and 1000.

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

(A) $\frac{1}{2}$. **(B)** $\frac{1}{32}$.
(C) $\frac{15}{16}$. **(D)** $\frac{1}{16}$.

d. A cantilever beam of length 'ℓ', flexural rigidity "EI" carries a load 'W' at a distance 'a' from the fixed end $(a < \ell)$, the deflection at the free end will be

(A) $\frac{wa^2}{6EI}(3\ell - a)$. **(B)** $\frac{w\ell^3}{3EI}$.
(C) $\frac{wa^2}{3EI}(2\ell - a)$. **(D)** $\frac{wa^3}{3EI}$.

e. The first moment of inertia of a semicircle about its diameter 'D' is given by

(A) $\frac{D^3}{32}$. **(B)** $\frac{D^3}{12}$.
(C) $\frac{\pi D^3}{32}$. **(D)** $\frac{\pi D^3}{12}$.

f. A rigid body in translation

(A) cannot move on a circular path.
(B) can move along a straight or curved path.
(C) must under go plane motion only.
(D) can move only in a straight line.

g. The instantaneous centre of rotation

(A) can exist for any space motion.
(B) should also be the instantaneous centre for acceleration.
(C) is a hypothetical concept.
(D) must exist for any plane motion.

h. The phenomenon of surface tension of liquid causes

(A) liquids to flow.
(B) liquids to resist flow and form a boundary layer.
(C) liquid surface to contract.
(D) liquids to adhere to the walls of container.

PART I

Answer any THREE Questions. Each question carries 14 marks.

Q.2 a. In the equilibrium position shown in Fig.1 the resultant of the three forces acting on the bell crank lever passes through the bearing 'O'. Determine the vertical force 'P'. Does this force P depend on 'θ'? **(8)**

b. Determine the resultant 'R' of the three tension forces acting on the eye bolts shown in Fig.2. Find the magnitude of resultant 'R' and the angle 'θ' which 'R' makes with the positive x-axis. **(6)**

Q.3 Determine the forces in all the members of the truss shown in fig.3. Indicate whether members are in tension or compression. (Use method of sections) **(14)**

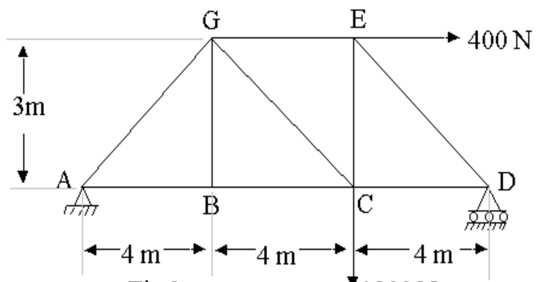
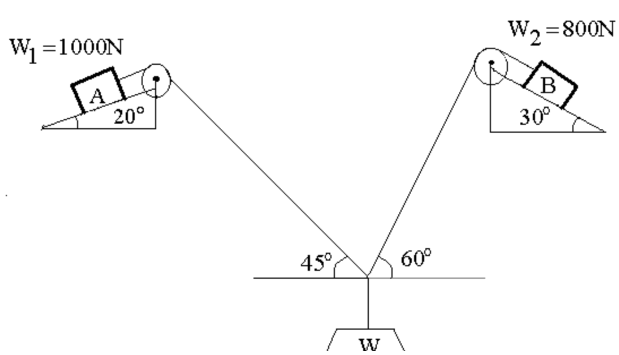


Fig.3

Q.4 Fig.4 shows an arrangement to keep the bodies A and B in equilibrium. Determine the least and the greatest magnitude of W for the system to remain in equilibrium. Find also for each case the tension in the ropes connecting the two bodies. Neglect friction at the pulleys. The coefficient of friction between Block A and the surface is 0.2 and for Block B and the corresponding surface is 0.25. **(14)**



Q.5 For the shaded area shown in Fig.5, find the moment of inertia about the line AB and BC. **(14)**

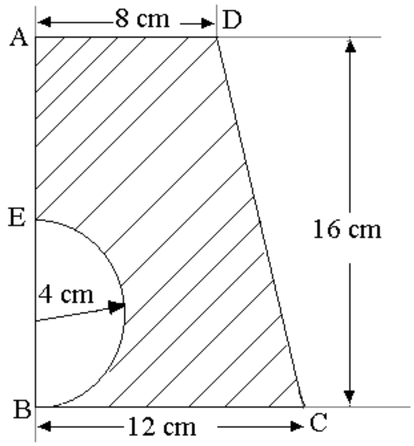


Fig.5

Q.6 A van of mass 800 kg and moving with a velocity of 12 m /sec strikes a car of mass 500 kg moving with a velocity of 9 m / sec in the same direction. Both the vehicles get coupled together due to impact. Find the common velocity with which the two vehicles will move. Also find the loss of kinetic energy due to the impact. Apply the principle of Impulse and Momentum. **(14)**

PART II

Answer any THREE Questions. Each question carries 14 marks.

Q.7 Draw S.F. and B.M. diagrams for the beam shown in Fig.6. **(14)**

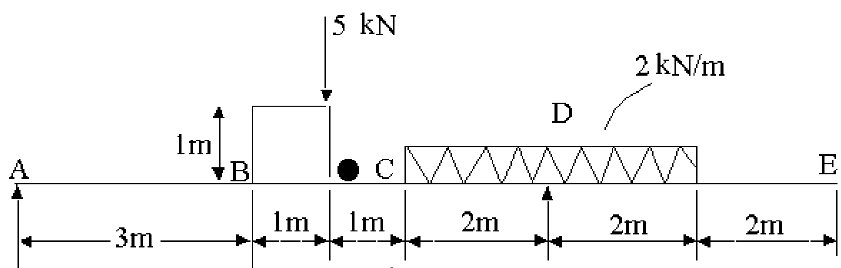


Fig.6

Q.8 A hollow steel shaft 3 m long must transmit a torque of 25 kNm. The total angle of twist in this length is not to exceed 2.5° and the allowable shearing stress is 90 MPa. Determine the inside and outside diameter of the shaft if $G = 85\, GN/m^2$ and inside diameter is 60% of the outside diameter. **(14)**

Q.9 Derive equations for total pressure and centre of pressure for

(i) a vertical plane surface submerged in liquid.

(ii) an inclined plane surface submerged in liquid. **(14)**

Q.10 A stream function is given by $\psi = 3x^2 - y^3$. Determine the velocity components in x and y directions and the velocity vector at point (3, 1). Further check if the potential function exists and if so, determine the same. **(14)**

Q.11 The force components on a reducing elbow, shown in Fig. 7 making a 60° turn with horizontal plane are to be determined. At the entering section 1 $D_1 = 6\text{m}, V_1 = 15\text{ m/sec}, P_1 = 282\text{ kPa}$ and at the exit section 2 $D_2 = 4.8\text{m}$. Specific gravity of flowing fluid is 0.9. Neglect elbow losses. **(14)**

DEC./2003

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Q.1 Choose the correct or best alternative in the following: **(2x8)**

a. Two forces each of magnitude P with included angle 120° act on a particle of mass m. Its acceleration would be

(A) 0. **(B)** $P/2m$.
(C) P/m. **(D)** $2P/m$.

b. The simplest resultant of parallel forces would be

(A) a force only. **(B)** a couple only.
(C) either a force or a couple. **(D)** both a force and a couple.

c. A block of weight W rests on a horizontal surface with a horizontal force P applied on it. The coefficient of friction is μ. If the force is decreased to P/2, the friction force on the block would be
(A) 0. **(B)** P/2.
(C) P. **(D)** μW.

d. The second moment of area of a square section of side b about a centroidal axis parallel to a side is $b^4/12$. Its value about a diagonal would be

(A) $b^4/3$. **(B)** $b^4/4$.
(C) $b^4/6$. **(D)** $b^4/12$.

e. A car covers first 20 km with a speed of 20 km/h and next 20 km with a speed of 60 km/h. The average speed of the car in km/h has been
(A)30. **(B)** 40.
(C) 50. **(D)** 60.

f. In the tension test of a mild steel specimen the nominal stress in the material is maximum at

(A) fracture. **(B)** ultimate load.
(C) yield point. **(D)** elastic limit.

g. If a cantilever beam is subjected to a couple at the free end then, one of the following quantities would have a quadratic variation along its length

(A) shear force. **(B)** bending moment.
(C) slope. **(D)** deflection.

h. In a pipeline, a manometer connected to the pipe line is used to measure the following

(A) static pressure. **(B)** stagnation pressure.
(C) velocity. **(D)** discharge.

PART I
Answer any THREE Questions. Each question carries 14 marks.

Q.2 A cylindrical tube C of radius R, weight W_C with both ends open, is placed on a smooth table with its axis vertical and contains two spheres A and B each of weight W and radius $r\,(R/2 < r < R)$, as shown in Fig.1. Show that the tube will tip over if $r/R < \left(1 - \frac{W_C}{2W}\right)$. **(14)**

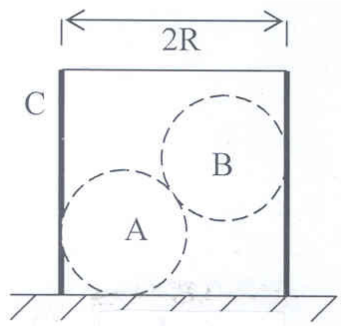

Fig. 1

Q.3 Find the forces and their nature in each member of the truss shown in Fig.2. **(14)**

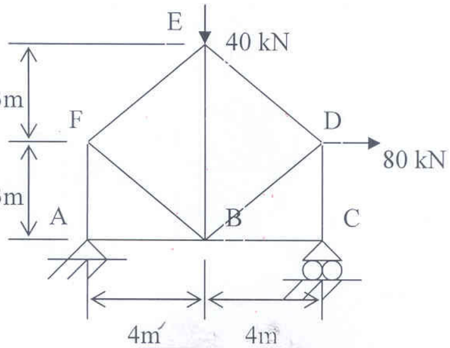

Fig. 2

Q.4 Determine the location of the centroid for the unequal Z-section shown in Fig.3. Also find the polar moment of area of the section about its centroidal axis. **(14)**

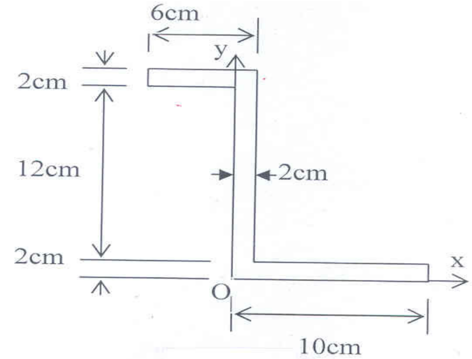

Fig. 3

Q.5 a. A train starts moving from rest with uniform acceleration along a circular curve of radius R = 800 m and reaches a velocity $v_1 = 36\,km/h$ after travelling a distance $s_1 = 600\,m$. Determine the velocity and acceleration of the train at the middle of this distance. **(7)**

b. A sphere of mass m_1, moving with velocity v_1 strikes another sphere of mass m_2, moving with velocity v_2 in the same direction $(v_1 > v_2)$. If the impact is perfectly elastic, show that the kinetic energy is conserved. **(7)**

Q.6 A uniform circular cylinder of mass m and radius R rolls down an inclined plane without slipping. The angle of inclination of the inclined plane to the horizontal is θ and the coefficient of friction is μ. Determine the angular acceleration of the cylinder and the acceleration of its mass centre. Find the frictional force on the cylinder and the condition for no slip. **(14)**

PART II

Answer any THREE Questions. Each question carries 14 marks.

Q.7 a. In a bridge truss a tension member is connected to the joint through a single pin of diameter d in double shear. The tension member is of uniform rectangular cross section with width b = 2d and thickness t. The safe tensile stress for the tension member is $\sigma = 157$ Mpa and the safe shear stress for the pin is $\tau = 80$ Mpa. If the maximum expected load is $P_{max} = 78.5\,kN$, determine the diameter d of the pin and the thickness of the tension member t. **(7)**

b. Derive an expression for discharge Q through a V notch with angle θ and the liquid level H above the base point. **(7)**

Q.8 Determine the diameter of a hollow steel shaft 2.5 m long to transmit a 25 kN-m torque without exceeding a shearing stress of 82 MPa and an angle of twist of 2.0°. Take the modulus of rigidity for steel as 82 GPa. If a solid shaft were required to be replaced for the above hollow shaft, determine its diameter and the percentage increase in weight. **(14)**

Q.9 A simply supported beam of length L, width b and depth h is subjected to a uniformly distributed load w per unit length over right half span. Draw the S.F. and B.M. diagrams. Determine the expression for the maximum bending stress in the beam. **(14)**

Q.10 a. A long square wooden block is pivoted along one edge and is in equilibrium when immersed in water to the depth shown in Fig.4. Find the specific gravity of the wood if there is no friction in the pivot. **(7)**

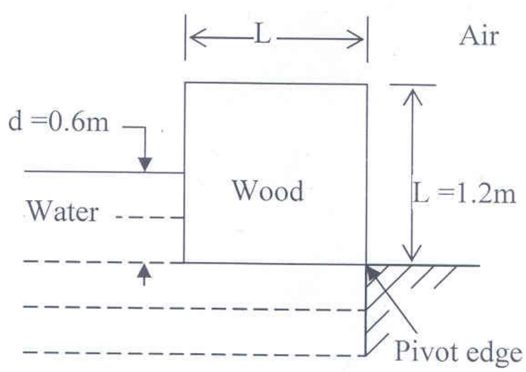

Fig. 4

b. Air flows steadily at low speed through a horizontal nozzle, discharging to the atmosphere. At the nozzle inlet, the area is 0.1 m^2. At the nozzle exit, the area is $0.02\ m^2$. Assume incompressible flow and no frictional losses. Determine the gauge pressure required at the nozzle inlet to produce an outlet speed of 50 m/s. Take the density of air as 1.23 kg/m^3. Also find the force required to hold the nozzle in place. **(7)**

Q.11 In a Francis turbine, water leaves the guide vanes at 15° and enters the runner blades in the radial direction. The constant velocity of flow is 8 m/s. The runner rotates at 350 rpm. The diameter at outlet is 0.6 times the diameter at inlet. The width of the wheel at inlet is 0.1 times the diameter at inlet and 5% of the area of the flow is blocked by runner blades. Calculate

a. The diameter of the runner at inlet and outlet.
b. The head.
c. The blade angles at outlet.
d. The power developed. **(14)**

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Q.1 Choose the correct or best alternative in the following: **(2x8)**

a. Which of the following quantities does not follow the parallelogram law of addition?

(A) Force **(B)** Velocity
(C) Linear Momentum **(D)** None of these

b. A projectile is launched with a velocity ν at an angle θ to the horizontal. The radius of curvature at the top of its trajectory would be

(A) $(\nu \cos\theta)^2 / g$ **(B)** $(\nu \sin\theta)^2 / g$
(C) ν^2 / g **(D** $\nu^2 \cos\theta / g$

c. A body rebounds after impacting a fixed smooth surface. If the impact is perfectly elastic, the following is conserved

(A) Momentum. **(B)** Kinetic energy.
(C) Momentum and Kinetic energy. **(D)** Velocity.

d. A particle of mass *m* is executing simple harmonic motion with circular frequency ω and amplitude *A*. The maximum force on the particle is

(A) mA **(B)** $mA\omega$
(C) $mA\omega^2$ **(D)** $m\omega^2$

e. In a standard uniaxial tension test on a specimen of diameter *d* and gauge length *L*, the yield stress would depend on

(A) material. **(B)** diameter *d*.
(C) gauge length *L*. **(D)** type of machine used.

f. A simply supported beam of span *L* is subjected to a concentrated load at a distance *L/3* from the left support. The maximum curvature of the beam would be at

(A) the centre. **(B)** left support.
(C) right support. **(D)** the point of loading.

g. The Froude number depends on the ratio of inertia force to

(A) Pressure force. **(B)** Viscous force.
(C) Gravity force. **(D)** sum of pressure force and gravity force.

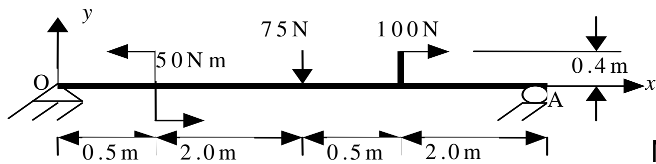
h. In flow through a pipeline, the hydraulic gradient line, with respect to the energy gradient line, is always

(A) the same. **(B)** below.
(C) above. **(D)** none of these.

PART I

Answer any THREE Questions. Each question carries 14 marks.

Q.2 a. Determine the resultant force vector F_R of the loads shown in Fig.1 on the beam OA and give its intercept x_R with the x axis. **(6)**



Not to scale

Fig. 1

b. A dam of rectangular section of height *h* and width *a* rests on a horizontal foundation shown in Fig.2. The weight density of water is υ and that of dam material as $υ_1$. Find the shear and normal forces exerted by the foundation on the dam. Determine the distance of the normal force from the end A. **(8)**

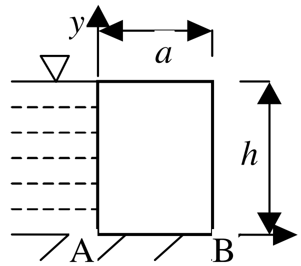


Fig. 2

Q.3 a. Find the forces in the members BF and BC using method of sections in the truss shown in Fig.3. **(7)**

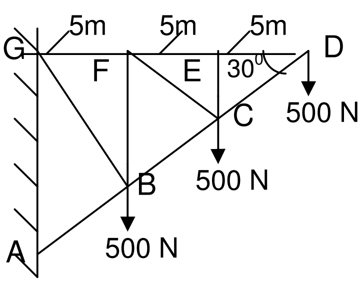
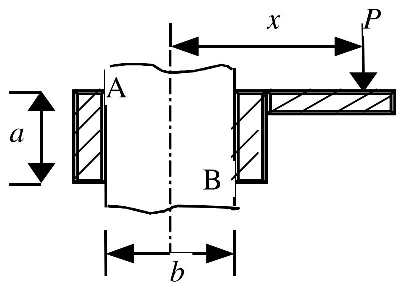


Fig.3

b. A light collar of a bracket has to support a load *P* as shown in Fig.4 with the coefficient of friction μ between the column and the collar. Show that for equilibrium of the collar at impending slip $x = a/2\mu$, the collar is in contact with the column only at A and B. **(7)**



Q.4 Determine the location of the centroid for the channel section shown in Fig.5. Also find the polar moment of area of the section about its centroidal axis. **(14)**

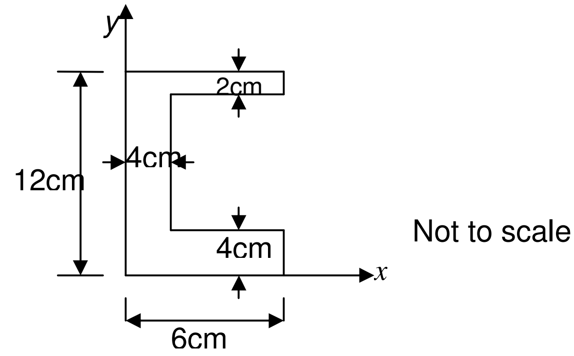


Fig.5

Q.5 a. A particle is moving in a circular path of radius 4 m in the *xy* plane with centre at the origin. At a point P (0, - 4) on the path, its speed is 4 m/s in the positive x direction and is increasing at the rate of 3 m/s^2. Find its acceleration. **(6)**

b. A bumper is designed to protect a 1100 kg car from damage when it hits a rigid wall at speeds up to 8 km/h. Assuming a perfectly plastic impact, determine the energy absorbed by the bumper during the impact. Determine the maximum speed at which this car can hit another 1100 kg car without incurring any damage if the other car is similarly protected and is at rest with the brakes released. **(8)**

Q.6 a. A disc C mounted on a bent rod rotates as shown in Fig.6 with constant angular speed $\omega_1 = 10$ rad/s relative to the bent rod ABC. The bent rod itself rotates at a constant angular speed of $\omega_2 = 5$ rad/s about the Z axis. Determine the angular velocity and angular acceleration of the disc with respect to the ground reference XYZ at this instant when BC is parallel to the Y axis **(6)**

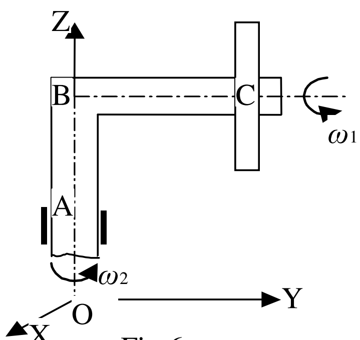


Fig.6

b. A uniform rod AB of weight *W* and length *L*, is supported by a pin connection at A and a wire at B as shown in Fig.7. Determine the angular acceleration of the rod and the acceleration of its centre of mass C at the instant the wire breaks. Also find the reaction force of the pin A at the instant the wire breaks. **(8)**

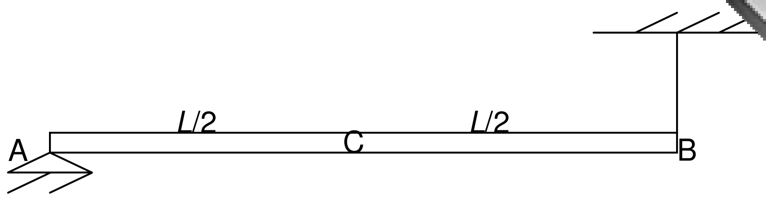


Fig.

PART II

Answer any THREE Questions. Each question carries 14 marks.

Q.7 a. A rod of length L and cross-sectional area A is subjected to tensile axial forces P at the ends. Determine the normal and shear stresses on a plane inclined at an angle of $45°$ to bar cross-section. **(7)**

b. A thin cylindrical pressure vessel with closed ends, mean diameter d =2000 mm and wall thickness t = 10 mm, is subjected to an internal pressure p = 0.8 Mpa. Determine the change in diameter of the cylinder. Take Young's modulus E = 200 Gpa and Poisson's ratio $\upsilon = 0.25$. **(7)**

Q.8 A simply supported beam is loaded as shown in Fig.8. Determine the support reactions. Draw the S.F. and B.M. diagrams for the beam and determine the critical values. **(14)**

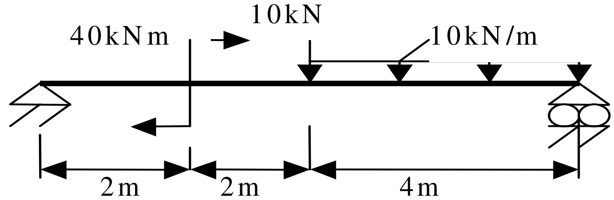


Fig. 8

Q.9 a. A solid circular shaft is connected to the drive shaft of an electric motor with a flanged coupling. The drive is taken by 8 bolts, each 12.5 mm in diameter on a pitch circle diameter of 230 mm. Find the shaft diameter if the maximum shear stress in the shaft is equal to that in the bolts. **(6)**

b. The mean bucket speed of a Pelton turbine is 15 m/s. The rate of flow of water supplied by the jet under a head of 42 m is $1 m^3/s$. If the jet is deflected by the buckets at an angle of $165°$, find the power and efficiency of the turbine. Take the coefficient of velocity $C_v = 0.985$. **(8)**

Q.10 a. A venturimeter with 7 cm throat diameter is fitted in a 15 cm diameter vertical pipeline with upward discharge. The absolute pressure at 6 m below the throat is 5 atm. while the pressure at the throat is such that it supports a column of 20 cm of water gauge. Estimate the discharge through the pipe. **(7)**

b. A one-sixth scale model of an automobile is to be tested in a wind tunnel at a speed corresponding to the prototype speed of 60 km/h. If only the inertial and viscous forces are important, determine the wind speed at which the model must be tested. If the model drag at that speed is 510 N, find the prototype drag. **(7)**

Q.11 a. The stream function $\Psi = V\left(r - R^2/r\right)\sin\theta$ represents 2D incompressible, irrotational flow around a circular cylinder of radius R. Determine the velocity field and obtain the stagnation points. Find the pressure distribution over the surface of this cylinder. **(7)**

b. Derive the velocity distribution for a fully developed incompressible laminar flow through a horizontal pipe. **(7)**