

1ST CLASS

APPLIED MECHANICS



1. A conical pendulum has a bob of 2 kg mass attached to the end of a piano wire 1.5 m long. It is set in motion with a horizontal circular radius of 500 mm.
   1) find the angular velocity
   2) the time to make one complete revolution of the bob
   3) the tension in the wire

Ans: 2.6338 rad/s Ref Reeds p118
Ans: 2.3856 seconds Ref JUN89
Ans: 20.8 N Ref MAR92

2. The stabilizing gyroscope of a ship has a mass of 50 tonnes, a radius of gyration of 1.525 m, and rotates about a vertical axis at 900 rev/min. Calculate:
   1) the time required to attain full speed after starting from rest, if the gyro is supplied with a constant power input of 75 kW
   2) the torque required to cause precession about the axis in a vertical fore and aft plane at the rate of 1°/s

note: power = Iw(alpha)
torque = Iw(omega)
where I = moment of inertia (kg m²)
w = velocity of spin (rad/sec)
(alpha) = angular acceleration (rad/s²)
(omega) = velocity of precession

Ans: 3.825 hours Ref DEC87
Ans: 191.2 Ref JUL89

3. Using strain energy methods, find the mass of a spring required to stop a truck of mass 10 tonnes, travelling at 0.91 m/s. Assume that there is no compression on the spring before contact with the truck.

note: $\rho_{(steel)}$ = 7380 kg/m³
$G_{(steel)}$ = 85 GPa
$\tau_{(steel)}$ = 280 MPa

Ans: 132.4 kg Ref MAY89
Ref FEB91

4. An axial thrust of 50 kN is carried by a plain collar type thrust bearing having inner and outer diameters of 250 mm and 400 mm respectively. Assuming that the coefficient of friction between the thrust surfaces is 0.02, and that the local wear rate of these surfaces is proportional to the pressure and to the rubbing speed, determine the power absorbed in friction of 120 rev/min.

Ans: 2.04 kW Ref Hannah p209 #1
Ref specimen

5. During a test on a car, the following information was obtained.

Velocity (m/s)	0	1.2	3.25	6.4	10.2	13.6	15.2	16.0
Time (seconds)	0	2.0	4.0	6.0	8.0	10.0	12.0	14.0

   1) Sketch the velocity/time graph
   2) find the velocity at 3.5 seconds
   3) calculate the distance travelled after 14 seconds

note: graph paper is required for this question

Ans: 4 m/s 2.735 Ref MAY89
Ans: 112 m Ref JUL89
Ref FEB91

6. A small air compressor is belt driven from a lay shaft in a workshop. The pulley on the compressor being 300 mm in diameter, and the angle of lap of the belt is 165°. When the belt is moved from the loose to the fast pulley, it slips for 8 seconds until the compressor attains its constant speed of 300 rev/min. The flywheel of the compressor has a moment of inertia of 4 kg m^2 and the friction requires a constant torque of 4 Nm. If the coefficient of friction is 0.28 during the acceleration period,

1) find the tensions in both reaches of the belt, and also
2) the distance that the belt slips and the energy lost in that time due to the belt slip.

note $\frac{T_1}{T_2} = e^{\mu\theta}$

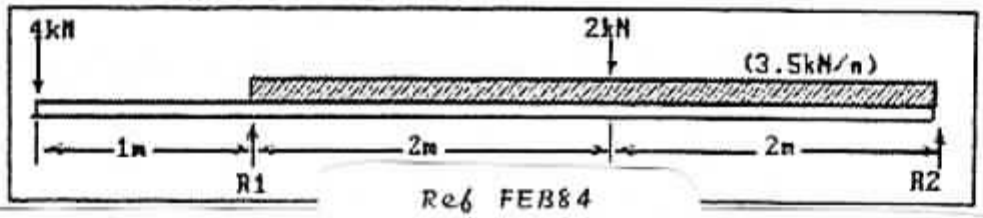
Ans: 237.4 N Ref Hannah p220
Ans: 106 N Ref specimen
Ans: 18.84 m
Ans: 2475.58 J

7. A belt drive consists of two v-belts in parallel, on grooved pulleys of the same size. The angle of the groove is 30 degrees. The cross sectional area of each belt is 750 mm^2 and μ = 0.12. The density of the belt material is 1.2 Mg/m^3 and the maximum safe stress in the material is 7 MN/m^3. Calculate;

1) the power that can be transmitted between pulleys of 300 mm diameter rotating at 1500 rev/min.
2) the shaft speed in rev/min at which the power transmitted would be at maximum

Ans: 171.66 kW Ref Hannah p217
Ans: 2807.7 rev/min Ref JAN88
Ref MAR91

8. A beam of uniform cross section has a uniformly distributed load of 200 N/m length, it also carries loads as shown. Draw the shearing force and bending moment diagrams.



Ref FEB84
Ref JUN87

9. A sluice gate of mass 6 tonnes, is subjected to a normal pressure of 2.5 MN. It is raised by means of a vertical screw which engages with a screwed bush fixed to the top of the gate. The screw is rotated by a 37 kW motor running at a maximum speed of 600 rev/min, a bevel pinion on the motor shaft gearing with a bevel wheel of 80 teeth keyed to the vertical screw. The screw is 125 mm mean diameter and 25 mm pitch. The u for the screw in the nut is 0.08 and between the gate and its guides is 0.10. If friction losses, additional to those mentioned above amount to 15% of the total power available, determine the maximum number of teeth for the bevel pinion.

Ans: 14 teeth Ref Hannah p195 #16
Ref specimen

10. A gear box is to be arranged for four speeds in approximate geometrical progression, one of which is to be a direct drive. The driving shaft transmits 30 kW at 2400 rev/min, and the speed of the driven shaft in lowest gear is to be approximately 400 and the layshaft is 180 mm and all teeth are 6 module. Find:
1) the necessary number of teeth in each pair of gears
2) the torque on the driven shaft
3) the torque on the gear-box frame in lowers gear neglecting friction

Ans: $T_A + T_J = 24$ Ref Hannah 254
$T_B + T_K = 36$ Ref FEB84
$T_C = 48$ $T_D = 12$
$T_E = 41$ $T_F = 19$
$T_H = 27$ $T_G = 33$
Ans: 716.22 Nm
Ans: 596.85 Nm in the direction of driving torque

IF CARRIES A LOAD OF 30 KN AT 3m FROM ONE END

11. A beam 20 meters long is simply supported at each end. It has a mass of 5000 kg. It also carries a load of 20 kN at 3 meters from the other end.
1) sketch and dimension the shearing force and bending moment diagrams.
2) calculate the position and magnitude of maximum bending moment

Ans: 10.2039 m from end on 30 kN side
Ans: 247.67 kNm magnitude Ref FEB91
Ref MAY89

12. The pressure on the piston of an engine is 1800 kPa when the crank has turned through an angle of 30 degrees past top dead centre. The piston diameter is 220 mm and the ratio of connecting rod length to crank is 4.5. Determine either graphically or by calculation:
1) the thrust in the connecting rod
2) the force required to overcome the friction of the guide

Ans: 68.883 kN Ref specimen
Ans: 188.86 N

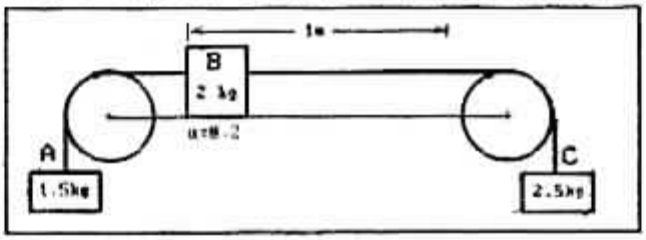
13. A curved stationary vane has an inlet angle of 30 degrees and an outlet angle of 20 degrees, both angles being measured from the normal to the vane. If the vane can withstand a force of 2 kN, determine the maximum diameter of a water jet allowed tangentially on to the inlet of the vane when the supply of water is from a reservoir 20 meters above the vane. Neglect friction and other losses in the pipe joining the nozzle to the reservoir and at the nozzle. Take density of water as 1000 kg/m³

Ans: 60 mm Ref specimen

14. The distance between the axles of a tanker milk truck is 2.56 m and its center of gravity is 2.45 m above the ground under fully loaded conditions. Calculate the speed at which the tanker will overturn when travelling around a bend of 50 m radius. Assume that the road is smooth and flat.

Ans: 57.53 km/hr Ref Reeds p111
Ref MAY89
Ref FEB91

15. Three masses A, B, and C of 1.5 kg, 2.0 kg, and 2.5 kg are arranged as illustrated. The coefficient of friction between B and the table surface is 0.2 and there is negligible friction in the pulleys. Starting from rest, find the velocity of B after it has travelled 1 meter.



Ans 1.4 m/s

Ref JAN88
Ref JUN89
Ref JUL89

16. A ship is pitching 10 degrees above and 10 degrees below the horizontal. Assuming the motion to be simple harmonic, having a period of 12 seconds, find the maximum angular velocity and angular acceleration of the ship during pitching

Ans: 0.0914 rad/s
Ans: 0.04785 rad/s²

Ref Hannah p79
Ref JAN88
Ref JUN89

17. 1) State what is meant by the parallel axis theorem.
2) The second moment of area of a rectangle about an axis through its centroid and parallel to the base is given by: $\frac{BD^3}{12}$

Calculate the polar second moment of a square section of side "s"

Ans: $\frac{s^4}{6}$

Ref: Hannah p8
Ref DEC87

18. A ball of 2 kg mass travelling at a velocity of 22 m/s overtakes another ball of mass 4.0 kg travelling in the same direction as the first ball but with a velocity of 10 m/s. In elastic conditions prevail and the coefficient of restitution is 0.80, calculate the velocity of the two balls after collision.

Ans: a) 17.2 m/s
b) 7.6 m/s

Ref Hannah p8
Ref DEC87
Ref DEC89

19. A torsional pendulum consists of a wire 0.5 m long, 10 mm diameter, fixed at its upper end and attached at its lower end to a heavy disk having a moment of inertia of 0.06 kg m². The modulus of rigidity of the wire is 44 GN/m². Find the frequency of torsional oscillation of the disk. If the maximum displacement to one side of the rest position is 5 degrees find the maximum angular velocity and acceleration of the disk.

Ans: a) 6.039 Hz
b) 3.31 rad/s
c) 125.61 rad/s²

Ref Hannah p78 # 7

20. A venturi meter is placed in a horizontal section of a pipeline, 120 mm diameter. The water pressure measured upstream of the meter is 700 kPa and at the throat of the meter, 650 kPa. The throat diameter is 60 mm and the coefficient of discharge is 0.98. Calculate the rate of the flow through the pipe (m^3/s).

Ans: 0.0286 m^3/s Ref FEB84
Ref JUN89

21. The impeller of a centrifugal pump has an outside diameter of 1000 mm, and inside diameter of 500 mm, and a vane entrance width of 170 mm. The radial velocity of the water through the impeller is 2.0 m/s when the pump rotates at 300 rev/min
Calculate:
1) The width of the impeller vane at exit.
2) The angle of the impeller vane at entrance so that water enters without shock.

Ans: 1) 85 mm Ref DEC83
2) 14.29° Ref DEC85
Ref DEC87
Ref JUL89

22. A canning machine has a particular component of mass 2.5 kg moving with SHM of amplitude 400 mm and 130 oscillations per minute. Calculate:
1) The maximum accelerating force upon the component,
2) The accelerating force when the component is displaced 300 mm from mid position.

Ans: 1) 185.2 N Ref FEB84
2) 138.9 N Ref MAY89
Ref FEB91
Ref APR91

23. A tank with sides 2 m long contains 1 m of sea water of [density 1.024], with 0.6 m of oil [density 0.8] above. Calculate the force on one side of the tank and the position of the centre of pressure.

Ans: a) 42.315 kN Ref: Reeds pg 338
b) 1.086 m below oil surface.

24. A worm and worm wheel have the following particulars:

Worm:	Worm wheel:
double threaded worm 70 mm Dia.	80 teeth
10 mm pitch	80 mm bearings
μ = 0.08	μ = 0.015
collar = 100 mm mean Dia.	output = 15 kW
μ = 0.06	rev/min = 20

worm square threaded Determine the input torque on the worm spindle and the overall efficiency.

Ans: a) 496.8 Nm Ref Hannah p192
b) 36% Ref APR85
Ref DEC86
Ref MAY89

25. A figure skater has just gone into a pirouette on one skate with both arms and other leg and foot extended. In this position, her angular velocity and moment of inertia are:
[W = 2 pi rad/s] [I = 4.5 kg/m²]
Neglect friction, calculate her angular when she pulls into the fast spin position. The moment of inertia during fast spin is 1.2 kg m²
Ans: 23.56 rads/s Ref DEC83
Ref MAR91

26. A girder of uniform cross section is 8 m long and supports a uniform distributed load of 400 kN. The girder is supported by three columns at the centre and both ends such that all support points are at the same level.
1) calculate the reactions in the columns
2) sketch the bending moment diagrams.
note: the deflections [S_1] at midspan due to a uniformly distributed load W and deflection [S_2] due to force P in outer columns are:

$$S_1 = \frac{5WL^3}{384EI} \qquad S_2 = \frac{PL^3}{48EI}$$

Ans: $R_1 = R_2 = 75$ kN Ref Reeds
$R_3 = 250$ kN Ref DEC85

27. A steel bar 30 mm diameter and 400 mm long is placed inside a brass tube. Outside diameter 40 mm and inside diameter 32 mm. The tube is 0.125 mm longer than the bar. This compound bar placed between rigid plates arranged so that the axial compressive force of 50 kN can be applied to the assembly. Calculate the stress set up in the tube and bar. E_s = 200 GPa, E_b = 90 GPa
Ans: o_s = 40.96 MPa Ref FEB84
o_b = 46.556 MPa Ref JAN88

28. A machine is driven through a reduction gear of ratio 9:1 by an electric motor. The armature, pinion and shaft which has a mass moment of inertia of 0.5 kg m². The mass moment of inertia of the machine components is 40 kg m². The torque developed by the motor when starting from rest is 30 Nm. The reduction gear efficiency is 95%. Calculate:
1) the brake power developed by the motor to drive the machine at a constant speed of 160 rev/min.
2) the time required for the speed of the machine to reach 60 rev/min from rest.

* AND THE LAUGH RESISTANCE MACHINE HAS A CONSTANT TORQUE OF 100 Nm

Ans: a) 1.764 kW $\frac{1.676}{.95}$ Ref Hannah p28
b) 3.15 s Ref DEC87
Ref MAY89
Ref DEC90
Ref FEB91

29. A venturi meter having an inlet diameter of 100 mm and a throat diameter of 30 mm is fitted to a pipe line conveying liquid of density 850 kg/m³. A mercury "U" tube is fitted between inlet and throat, and the surfaces of separation have a difference of levels of 200 mm. Assuming a discharge coefficient of 0.96, calculate the mass of flow of the liquid.
note: the density of mercury is 13.6 x 10^3 kg/m³
Ans: 4.44 kg/s

30. 1) Sketch the controlling force for a Porter type governor using centripetal force for the ordinate and radius for the abscissa.
2) Sketch the controlling force for a Hartwell type governor using a similar coordinate system.
a) Illustrate stable, unstable, and isochronous conditions.
3) A Porter type governor has 300 mm arms and the rotating balls each have a mass of 1.8 kg. At the mean speed of 120 rev/min, the arms are at a angle of 30 deg to the vertical axis. Calculate the central dead load of the governor.

Ans: 5.728 kg Ref Hanna p155
Ref DEC83

31. A joint is held together by a cotter having a taper of 1:10 equally divided between the two edges. The cotter has a coefficient of friction, u, of 0.18 and is driven into the joint by a force of 500 N. Calculate the force:
1) fastening the joint together.
2) required to eject the cotter.

Ans: a) 1077.7 N Ref Reeds pg 159 #6
b) 277.6 N Ref Dec87

32. 1) Derive an expression for the maximum shear stress "T" for a closed-coiled helical spring, where the mean diameter is "D", the wire diameter is "D" and the axial load "W".
2) A close-coiled helical spring has an axle load of 90 N and the mean diameter is 8 times the diameter of the wire Allowing a maximum shear stress of 105 MPa, find the diameter of the wire.

Ans: 1) $T = \frac{8WD}{\pi d^3}$ Ref JUN89
Ref Reeds 310
2) 4.18 mm

33. An engine is designed to develop 10 kW of power at a mean speed of 1000 rev/min. Find the moment of inertia in kg m², of a suitable flywheel, assuming a speed variation of 1.5% of the mean speed and an energy fluctuation equal to 0.9 of the work done per revolution.

Ans: 1.664 kg m² Ref: Reeds pg 104

34. Water is pumped from a fire engine to the nozzle of a hose being used to fight a fire, the nozzle is 30 m above the pump outlet. The nozzle outlet diameter is 25 mm and the velocity of the water pumped through it is 28 m/s. Determine the quantity of water flowing through the nozzle per second and the power of the pump if losses are neglected. Take density of water as 1000 kg/m³.

Ans: a) 13.7445 kg/s Ref specimen
b) 4045 W

35. A Reciprocating engine having a stroke of 600 mm operates at 400 rev/min. calculate the velocity and acceleration of the piston when the crank has turned 30 deg. past top dead center. neglect the effect of connecting rod angularity.

Ans: a) 6.28 m/s Ref DEC83
b) 455.86 m/s² Ref DEC85

36. A spring of stiffness 200 N/m and 0.75 kg mass is set in motion when a mass of 5 kg is attached to the free end. calculate the oscillations:
1) when the spring mass is excluded.
2) when the spring mass is included.
note: 1/3 of spring mass has effect on the hook.

Ans: 1) 1.006 Hz. Ref Hannah p68
2) 0.982 Hz. Ref APR84
Ref JAN88

37. A uniform ladder rest on a rough horizontal deck leaning against a rough vertical bulkhead. When the ladder makes an angle of 60 deg. to the deck, it is just on the point of slipping. If the coefficient of friction between the foot of the ladder and the deck is 0.27 calculate the coefficient of friction between the top of the ladder and the bulkhead.

Ans: 0.24 Ref Reeds p588

38. A turnbuckle has right hand single start square threads of 8 mm pitch, 28 mm pitch diameter, and the coefficient of friction between screw and nut is 0.15. The device is used to tighten a steel stay having a cross sectional area of 80 mm², a length of 46 m and a modulus of elasticity, E=140 GPa. If the stay is preloaded to 1.8 kN. Calculate:
1) energy to tighten the stay one more revolution of the turn buckle.
2) energy lost of friction while tightening the stay.

Ans: 1) 161.1 J Ref Hannah p190
2) 101.14 J Ref DEC83
Ref FEB84
Ref MAR85
Ref DEC85
Ref APR91

39. 1) Show that the elastic strain energy of a hollow shaft subject to torsional stress is given by:

$$U = \frac{[\pi^2]}{[4g]} \left[\frac{D^2 + d^2}{D^2}\right] \times \text{volume of shaft}$$

Where: u = Elastic strain energy
D = Outside diameter
d = inside diameter
G = Modulus of rigidity

2) A solid shaft 150 mm diameter is to be replaced by a hollow shaft of similar material of the same length and have the same mass. The strain energy taken by the hollow shaft is 20% greater torque than can be taken by the solid shaft with the same stress. Find the outside and the inside diameter of the hollow shaft.

Ans: Ref Reeds #13-13
Ref JUL89

40. A tank 10 m long, 4 m wide, and 6 m high is filled with oil (rd 0.9) and the oil rises to a height of 5 m up a vertical pipe above the top of the tank. Calculate the load on one end plate and on the bottom of the tank.
Ans: a) 1695.17 kN Ref Reeds p331
Ans: b) 3884.76 kN

41. A bolt and nut falls into a deep tank and the sound of the splash when it strikes the liquid is heard after 2.2 seconds. Estimate the ullage of the tank if the velocity of the sound is 335 m/s a the ambient temperature of the air.
Ans: 22.32 m Ref specimen

42. The blades of a three blade propeller has masses of 10.20, 10.25 and 10.20 kg . Their centers of gravity are 300 mm, 299 mm and 301 mm respectively from the center of rotation. the angles are all 120 degrees. Calculate the out of balance force developed at 800 rev/min.
Ans: 62 N Ref FEB84

43. A cylindrical pressure vessel as the longitudinal seam welded in the form of a helix. The helical seam is inclined at an angle of 56 degrees to the circumferential seam, the inside diameter of the vessel is 1.8 m, the shell thickness 30 mm, and the working pressure is 3500 kPa. Calculate:
1) the tensile stress normal to the circumferential seam.
2) the tensile stress normal to the oblique seam.
Ans: a) 52.5 MN/m^2 Ref specimen
b) 88.58 MN/m^2

44. A satellite is placed in a circular orbit 650 km above the earth's surface at a latitude of 45 degrees. At sea level,
g = 9.80665 m/s^2, and the earth's mean radius is 6380 km.
1) calculate the speed to maintain the orbit.
2) find the period of one revolution.
Ans: 1) 27127 km/hr Ref DEC83
2) 1.628 hr Ref DEC85
Ref FEB90
Ref MAR91

45. A container of mass 2 tonnes is being lowered by a winch at the rate of 0.6 m/s. The cable supporting the load has a cross sectional area of 1200 mm^2 and a modulus of elasticity of 200 GPa. When 15 m of cable has been unwound from the which drum, the brake is suddenly applied.
1) find the maximum stress in the cable due to sudden braking.
2) find the maximum extension of the cable.
Ans: a) 89.44 MN/m^2 Ref DEC83
b) 6.71 mm Ref DEC85
Ref JUN89
Ref JUL89

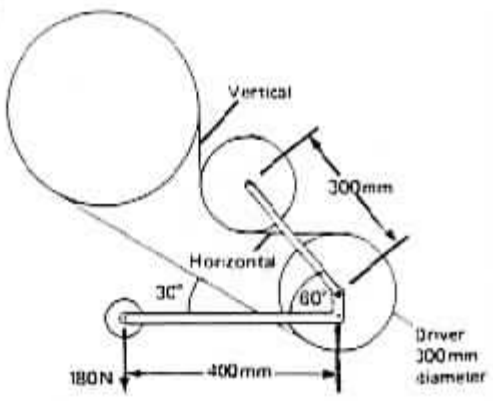
46. A flywheel has a mass of 100 kg, radius of gyration 0.8m diameter of 0.8 m. It increases speed from 50 rev/min to 2000 rev/min in 10 seconds. Find the accelerating torque.
Ans: 1306.9 Nm Ref JAN88

47. A spherical gas storage tank is 25 m diameter and constructed of 13 mm plate, the welded seams of which may be considered as being 90% of the plate strength. The yield strength of the material is 245 MPa and a factor of safety of 2.5 is deemed adequate. Calculate the maximum permissible pressure the sphere may safely withstand.
Ans: 254 kPa Ref DEC87
Ref MAY89
Ref FEB90
Ref FEB91

48. A balloon is rising with a velocity of 5 m/s when a sand bag, used for ballast, is released. At the instant when the sand bag is released, the balloon is 420 m above the earth. Calculate the time required for the sand bag to reach the ground.
Ans: 9.78 seconds Ref DEC87

49. A cone clutch has a mean surface diameter of 300 mm a face width of 65 mm, and the inclined angle between the friction faces s 30 deg. The clutch lining as a coefficient of friction, u=0.3, and the normal pressure acting upon the surface is 70 pa. Calculate:
1) the maximum power that can be transmitted when rotating at 1200 rev/min.
note: assume uniform wear theory.
Ans: 22.9 kW Ref Hannah p202
Ref DEC87
Ref DEC89
Ref MAR91

50. The diagram shows a belt drive fitted with a gravity idler. The driver rotates anti-clockwise at 360 rev/min and the coefficient of friction between the belt and pulley is 0.3. Determine the initial belt tension and the power transmitted. Neglect any lag in the belt.
Ans: a) 175.7 N Ref Hannah ??
b) 1987 W Ref JAN88
Ref JUN89
Ref FEB90



51. A mass of 10 kg is laying on a smooth (frictionless) surface of a wheel inclined at 30 degrees. It is attached by a wire 2 m in length parallel to the plane to centre of the wheel. The wheel revolves at 10 rev/min. Find the tension in the wire.

Ans: 65.47 N

Ref MAY89
Ref JUL89
Ref FEB91

52. A police car equipped with a radar speed detecting device observes a motorist travelling at a speed of 120 km/hr. The police car starts pursuing the motorist 30 seconds after the initial observation and accelerates to 160 km/hr during a 20 second time interval. Assume both vehicles maintain their speeds on a straight unimpeded road.

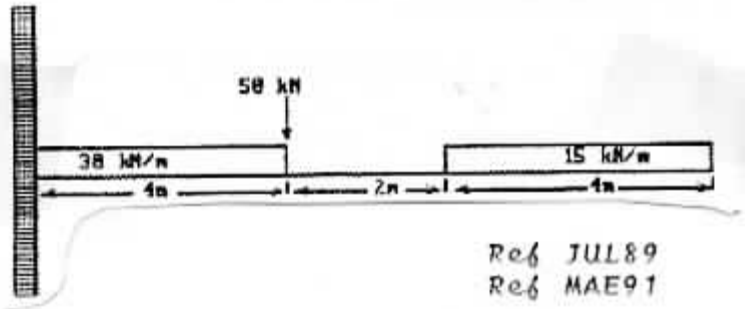
1) sketch a displacement/time graph of the events
2) calculate the time and the distance transversed from the moment of the original observation until the chase ends.

note: graph paper is required for this solution.

Ans: 160 s
Ans: 5333.3 m

Ref FEB84

53. A cantilever beam is loaded as shown in the diagram below. Neglecting the weight of the beam, sketch the shear force and bending moment diagrams.



Ref JUL89
Ref MAE91

54. A rectangular bar of uniform section 200 mm x 30 mm is used as a structural member and is subjected to a tensile load of 500 kN at 5 mm to one side of the 200 mm axis. Calculate:

1) the maximum and minimum stress induced in the outer fibers of the member
2) sketch the stress distribution across the section

Ans: 95.8 MN/m² (tensile)
208.3 MN/m²
Ans: 70.8 MN/m²
41.67 MN/m²

55. 1) State what is meant by the parallel axis theorem ?)

The second moment of area of a rectangle about an axis through its centre and parallel to the base is given by: $\frac{BD^3}{12}$ Calculate the polar second moment of a square section of side "S".

Ans: $I_P = \frac{S^4}{12}$

Ref DEC87
Ref JAN88
Ref JUN89

56. A simple pendulum consists of a spherical mass of 10 kg attached to the end of a length of piano wires. The upper end of the wire attached to a jewelled bearing arrangement on the ceiling to reduce friction.

1) Find the length of wire
2) the angular acceleration 1.5° from the vertical position

Ans: 24.85 m Ref MAR91
Ans: 0.01033 rad/s²

57. A pontoon 18 m long and 3 m wide floats level in calm water and carries two points loads of 108 kN , 4 m from each end.

1) Draw shearing force and bending mament diagrams for the pontoon, showing all important values
2) Given the density of the water to be 1000 kg/m³, determine the increase in draught of the pontoon due to the two applied loads.

Ans: 0.4077 m

58. An undersea research vehicle has a spherical hull of 1 m radius and 40 mm thickness. The hull is constructed of high strength alloy steel having a yield point of 700 MPa. Neglecting the adverse effect of entrance ports cut into the hull determine the depth the vessel may be submerged to set up a stress equal to that of the yield point.
Ans: 5540 m

59. A rectangular tank of dimensions : 2 m by 1.4 m by 1 m deep contains fresh water to a depth of 0.6 m. A block of wood of mass 156 kg is then placed so that it floats freely upon the surface of the water. Calculate the load (kN) on the bottom of the tank:

1) before the block is placed on the water
2) after the block is placed on the water

Ans: 16.48 kN
Ans: 18 kN

60. A homogeneous disc of uniform thickness has a mass of 8 kg and diameter of 400 mm. The disc is suspended by a wire 4 mm diameter and 1 m long in such a way that it hangs perfectly horizontal with the wire attached to its geometrical centre. The system now set in torsional oscillations and is displaced at the rate of 20 complete oscillations during 62 seconds. Calculate the Modulus of Rigidity [G] of the wire.
Note: $T = 2\pi\sqrt{\frac{I_o L}{JG}}$

61. In a Porter governor the upper and lower arms are each 200 mm long, and are each inclined at 30° to the vertical when the sleeve is in its lowest position. The points of suspension are each 36 mm from the axis of the spindle. The mass of each rotating ball is 3 kg, and that of the central load on the sleeve 20 kg. If the movement of the sleeve is 36 mm, find the range of speed of the governor.
Ans: 170.6 - 185.4

62. On a pachaging machine mechanism a crosshead moves in a straight guide with a S.H.M. at distances of 125 mm and 200 mm from its mean position. The crosshead has velocities of 6 and 3 m/s respectively. Determine:
1) the amplitude
2) the maximum velocity
3) the periodic time
4) If the crosshead has a mass of .2 kg what is the maximum inertia force?

Ans: .2193 m
Ans: 7.31 m/s
Ans: .1885 s
Ans: 48.7N

63. A hollow shaft is coupled to a solid shaft. The ends are secured against movement and a torque of 6 kNm is applied at the junction of the shafts.
Calculate:
1) the torque transmitted by each shaft
2) the angular movement of the coupling

note: the Modulus of Rigidity for both shafts is 83 GN/m²
Ans: 3.58 kNm
Ans: 2.42 kNm
Ans: 1.35°

64. A vehicle is uniformly accelerated from rest up to maximum speed, taking one minute and travelling a distance of 0.5 km. It then runs at maximum speed for 2 minutes and finally uniformly retarded for 30 seconds to bring it to rest.
1) Find the maximum speed.
2) Sketch a velocity time graph
3) Find the total distance travelled

Ans: 60 km/h
Ans: 2.75 km

a cliff 80 m high. The initial velocity of the stone is 20 m/s in a horizontal direction. Calculate

1) the time required for the stone to strike the ground
2) the horizontal distance covered by the stone during this time.

Ans: 4.0385 s
Ans: 80.77 m

66. A projectile is fired from a cannon with an initial velocity of 900 m/s at an angle of elevation of 30° to the horizontal. Find:

1) the maximum height
2) the time of flight
3) the horizontal range

Ans: 10321.1m
Ans: 91.74 s
Ans: 71.502 km

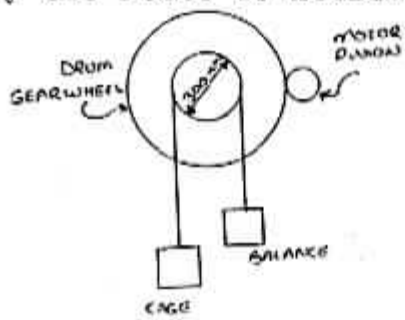
67. A truck of mass 5000 kg moving at 10.8 km/h collides with another truck of mass 9500 kg moving in the opposite direction at 18 km/h. At impact they lock and move on together. Calculate:

1) the common speed and direction after impact
2) the loss of kinetic energy at impact

Ans: 8.069 km/h in direction of larger mass
Ans: 104.84 kJ

68. The elevator mechanism shown consists of a rotating drum of mass 2000 kg and radius of gyration 180 mm. A motor armature of mass 300 kg and radius of gyration 120 mm. A cage of mass 1800 kg and a balancing mass of 1000 kg. The ratio of trunion (pinion) to gear is 1:12 and the motor must supply a torque of 200 Nm to overcome bearing friction. The elevator is lowered at a constant rate of 2 m/s but de-accelerates when it approaches the bottom floor at a constant 0.1 g m/s². Calculate:

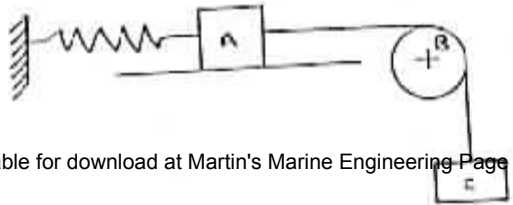
1) the distance travelled during the deacceleration period
2) the braking torque required if the brake is attached to the motor shaft



Ans: 2.0387 m
Ans: 307 Nm

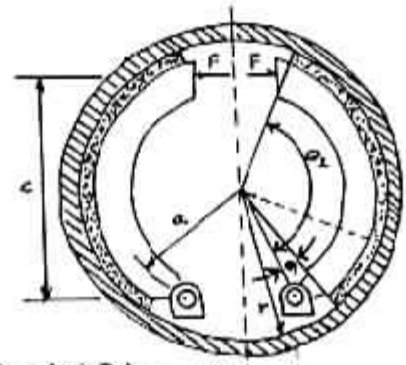
69. In the system illustrated the spring of stiffness 800 Nm is initially compressed 40 mm while all of the components are held in position by a locking device attached to block "A". Load "C" has a mass of 15 kg. The pulley "B" of diameter 200 mm has a mass moment of inertia of 0.4 kgm². Block "A" has a mass of 20 kg and the co-efficient of friction between the plane and block "A" is 0.3. The system is now set in motion by releasing the locking mechanism. Calculate the velocity of "C" after it drops through a distance of 100 mm.

Ans: 0.4627 m/s



70. Using the data provided, calculate the braking torque for the internal brake shown:

$\Theta_1 = 10°$
$\Theta_2 = 130°$
$\Theta_m = 90°$ IF $\Theta_2 > 90°$
$\Theta_m = \Theta_2$ IF $\Theta_2 < 90°$



brake diameter = 300 mm
shoe face width = 50 mm
right shoe pressure P_m = 1520 kPa
left shoe pressure P'_m = 480 kPa
Ans 1.0986 kNm

$$T = \mu W r^2 \left(\frac{\cos\Theta_1 - \cos\Theta_2}{\sin\Theta_m} \right) (P_m + P'_m) \text{ kg}$$

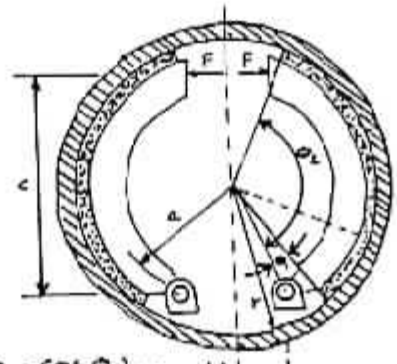
71. A steel bar of 2580 mm² cross-section area is placed inside a brass tube of 3225 mm² cross-sectional area, jointly support a compressive load of 420 kN. Calculate the stresses after compression, taking the Modulus of Elasticity as:
E(steel) = 207 GN/m²
E(brass) = 92 GN/m²
Ans: 46.51 MN/m²
Ans: 104.65 MN/m²

72. A steel bar 30 mm diameter and 400 mm long is placed inside a brass tube of outside diameter 40 mm and inside diameter 32 mm. The tube is 0.125 mm longer than the bar. This compound bar is placed between rigid plates arranged so that an axial compressive force of 50 kN can be applied to the assembly. Calculate the stresses set up in the tube and the bar.
note: ES(steel) = 200 GPa Ref Feb84
note: ES(brass) = 90 GPa
Ans: 46.544 MPa
Ans: 40.947 Mpa

73. A steel cylinder liner 70 mm inside diameter and 90 mm outside diameter is to be hydrostatically tested to a pressure of 3000 kPa. Two endplates are arranged to cover the open ends of the cylinder and are held in place by four-12 mm diameter through-bolts. The effective length of the bolts = (1.10) the cylinder length. If the nuts are tightened until the bolts are stressed to 30 MPa, calculate the stresses in the bolts and in the cylinder. Assume the end plates remain perfectly rigid.
note: ES(steel) = 200 GPa.
Ans: 33.6 MPa (tensile)
Ans: 1.45 MPa (compressive)

74. A short hollow cylindrical column is 250 mm outside and 25 mm thick and supports an axial compressive load of 400 kN, the line of action of which is 20 mm from the centre of the column.
1) Find the maximum and minimum stresses in the column
2) Find the maximun eccentricity of loading so that the stress on one side is zero
Ans: 31.463 MN/m²
Ans: 13.797 MN/m²
Ans: 31.24 mm

70. Using the data provided, calculate the braking torque for the internal brake shown:



brake diameter = 300 mm
shoe face width = 50 mm
right shoe pressure P_m = 1520 kPa
left shoe pressure P_m = 480 kPa
Ans 1.0986 kNm

$$T = \mu w r^2 \left(\frac{\cos\theta_1 - \cos\theta_2}{\sin\theta_m} \right) (P_m + P'_m) \text{ kgf}$$

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Ans: 46.51 MN/m²
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72. A steel bar 30 mm diameter and 400 mm long is placed inside a brass tube of outside diameter 40 mm and inside diameter 32 mm. The tube is 0.125 mm longer than the bar. This compound bar is placed between rigid plates arranged so that an axial compressive force of 50 kN can be applied to the assembly. Calculate the stresses set up in the tube and the bar.
note: ES(steel) = 200 GPa Ref Feb84
note: ES(brass) = 90 GPa
Ans: 46.544 MPa
Ans: 40.947 Mpa

73. A steel cylinder liner 70 mm inside diameter and 90 mm outside diameter is to be hydrostatically tested to a pressure of 3000 kPa. Two endplates are arranged to cover the open ends of the cylinder and are held in place by four-12 mm diameter through-bolts. The effective length of the bolts = (1.10) the cylinder length. If the nuts are tightened until the bolts are stressed to 30 MPa, calculate the stresses in the bolts and in the cylinder. Assume the end plates remain perfectly rigid.
note: ES(steel) = 200 GPa.
Ans: 33.6 MPa (tensile)
Ans: 1.45 MPa (compressive)

74. A short hollow cylindrical column is 250 mm outside and 25 mm thick and supports an axial compressive load of 400 kN, the line of action of which is 20 mm from the centre of the column.
1) Find the maximum and minimum stresses in the column
2) Find the maximun eccentricity of loading so that the stress on one side is zero
Ans: 31.463 MN/m²
Ans: 13.797 MN/m²
Ans: 51.24 mm

75. A short hollow cylindrical column of outside diameter 300 mm and wall thickness 25 mm supports an axial compressive load of 500 kN acting at a distance of 25 mm from the geometric centre of the end of the column.
Calculate:
1) the maximum and minimum stresses in the column
2) the maximum eccentricity of loading so that the stress in one side of the column is zero.

Ans: 32.25 MPa
Ans: 14.05 MPa
Ans: 63.58 mm

76. A solid cylindrical steel stay is expanded at one end to a diameter of 150 mm to accomodate a cotter of rectangular cross-section. The width of this cotter is to be six times its thickness. The tensile strength of the stay material 460 MPa the shear strength of the cotter material 340 Mpa, and the factor for double shear may be taken as 1.8. Calculat:
1) the thichness of the cotter
2) the depth of the cotter
3) the diameter of the stay if the factor of safety is the same throughout

Ans: 38.58 mm
Ans: 234 mm
Ans: 124.33 mm

77. A cantilever beam of uniform section is 3 m long and made of four steel plates welded together, 200 mm deep and 120 mm wide. The side plates are 15 mm thich, top and bottom plates are 25 mm thick. Stress should not exceed 45 MPa [MN/m^2]. Calculate the maximum concentrated mass that can be supported at the free end. RELATIVE DENSITY = 7.86

Ans: 712 kg

78. Calculate the torque that may be applied to a solid cylindrical shaft, 40 mm diameter. The maximun allowable working stress is 90 MPa.
At a later period it was decided to replace the solid shaft with a hollow one constructed of high strength steel having a maximum allowable working stress of 180 MPa so the torque may be increased 80%. Calculate the inside diameter of the hollow shaft
note: $\frac{T}{J} = \frac{T}{r} \quad \frac{G\theta}{L}$

Ans: 1131 Nm
Ans: 22.5 mm

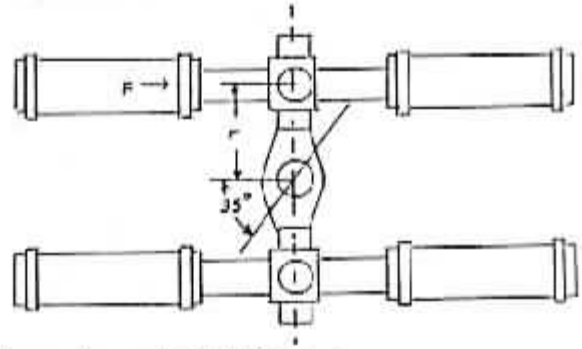
79. A composite shaft is constructed of a steel tube surrounded by a bronze liner that has been shrunk in place so that the strain on the two materials will be identical. The shaft is 3 m long and the outside diameter of the bronze liner is 300 mm. If the shaft is designed so that the maximun shear stress in each material is limited to 11 MPa when a torque of 60 kNm is applied, calculate:
1) the interface diameter of the steel and bronze
2) the inside diameter of the steel tube
3) the angle of twist of the arrangement (radians)

Ans: 65.625 mm
Ans: 7.875 mm
Ans: 0.0063 rads

80. A close coiled helical spring is to carry a load of 90 N and the mean coil diameter is to be eight times the wire diameter. Calculate the wire diameter and the coil diameter if the maximum shear stress is limited to 105 MPa
Ans: 33.6 mm

81. In a four ram electric-hydraulic steering gear, the relief by-pass valves are set to lift when the oil pressure is 7500 kPa. The diameter of the rams is 300 mm, distance from the centre of the ridder stack to centre-line of each pair of rams is 750 mm and the maximum angle of helm is 35° from the mid-position. The diller rams are parallel round section from the end to 600 mm from the rudder stock centre and the maximum bending stress in them may be taken as accumming at this sec.. Calculate :

1) the diameter of the rudder stock to limit the maximum torsional stress in it to 70 MPa
2) the diameter of the tiller arms to limit the maximum bending stress in them to 100 MPa.



Ans: 442 mm
Ans: 275 mm

82. An engine shaft 360 mm diameter, when transmitting a certain power, is twisted one degree over a length of 4.5 meters. Calculate the torque of this solid cylindrical shaft and the shear stress at the outer fibers if the modulus of Rigidity of the shaft material is 103.5 GPa [GN/m²]
note: $\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$
Ans: 661.9 kNm
Ans: 72.25 MN/m²

83. A solid steel shaft 240 mm diameter has a bronze liner shrunk on it over its entire length, the outside diameter of the liner being 290 mm. Calculate:

1) the ratio of the stresses in the shaft and liner
2) the maximum stresses in the shaft and liner
3) the angle of twist over a length of 4 m when the torque transmitted is 100 kNm.

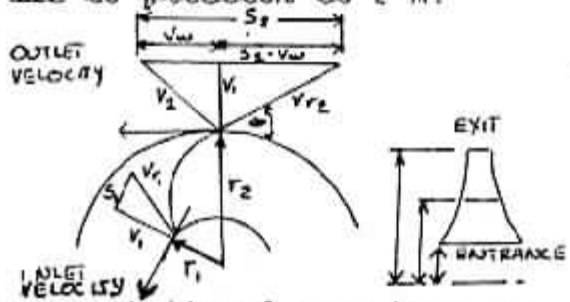
Take the Moduli of Rigidity for steel and bronze as 90 and 42 GN/m² respectively and assume no slipping between shaft and liner.
Ans: 1.773:1
Ans: 24.11 MN/m²
Ans: 13.59 MN/m²
Ans: 0.5118°

84. Coloured water is used as the manometric liquid in a Prandtl tube used for measuring the air velocity in a wind tunnel. If the difference in height of liquid in the manometer column is 20 cm, calculate the velocity of the air.
note: air density $(1.3)(10^{-3})(g/cm^3)$

85. A storage tank contains oil at a height of 10 m above the discharge opening which has a diameter of 50 mm connected to a horizontal pipe fitted with a valve to control the flow. The loss of head at entrance to the pipe = $\frac{0.5\ v^2}{2}$ J/kg and at the valve = $\frac{0.2\ v^2}{2}$ J/kg. The loss of energy due to pipe friction = 2 J/kg of flow and the relative density of oil = 0.8. Calculate the mass rate of flow when the valve is fully open.
Ans: 16.702 kg/s

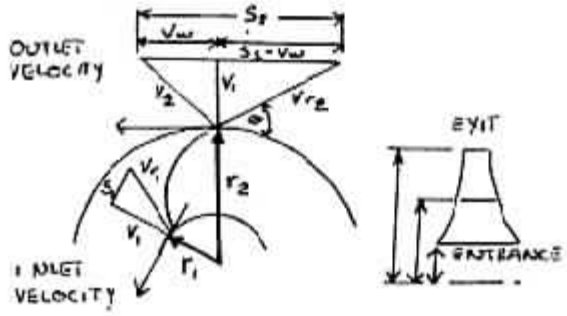
86. A jet of water flows horizontally through a nozzle 55 mm diameter until it strikes a flat stationary plate placed at right angles to the jet. The force required to hold the plate in position against that of the jet is 300 N. Assume no losses due to friction or splashing occur, calculate the initial velocity of the jet.
Ans: 11.24 m/s

87. The impeller of a centrifugal pump has an outside diameter of 355 mm and rotates at 1000 rev/min. The blades are curved backward at an angle of 150° to the direction of rotation and the radial velocity of the liquid through the impeller is 2.4 m/s. The head measured across the pump amounts to 11.7 m and the loss due to friction is 2 m. Calculate the pump efficiency.



Ans: 79.36%

88. The vanes of an impeller in a centrifugal pump have an exit angle of 45° radial velocity = 2.004 m/s. Using the information and diagrams given, calculate the theoretical head and the manometric efficiency.

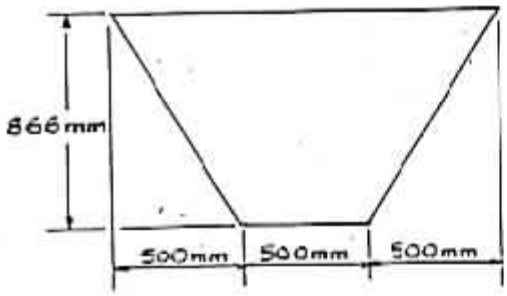


Ans: 11.74 m
Ans: 68.1 %

89. A storage tank containing fresh water has a 10 m head above a hollow 20 mm diameter in the side of the tank through which the water escapes. Taking the coefficent of velocity as 0.97 and the coefficeincy of reduction of area as 0.64 calculate:
1) the velocity of the water jet as it leaves the hole
2) the mass rate of flow of water escaping in tonnes per hour.
Ans: 13.587 m/s

90. Fresh water flows through a horizontal venturi meter which has diameters at entrance and throat of 150 mm and 50 mm respectively. The difference in pressure between these two points is measured by a submerged "U-tube" containing mercury and water. Taking the specific gravity of mercury as 13.6 and the discharge coefficeint for the meter as 0.9, calculate the mass flow of water per hour through the meter when the recording on the "U-tube" is 50 mm of mercury.
Ans: 22.51 Mg/hour

91. The figure shows the vertical end of a symmetrical tank 5 m long. The tank is completely filled with water of density 1020 kg/m³ Determine the hydrostatic load on :
1) each sloping side
2) the vertical end
Ans: 23.5 kN
Ans: 3.14 kN

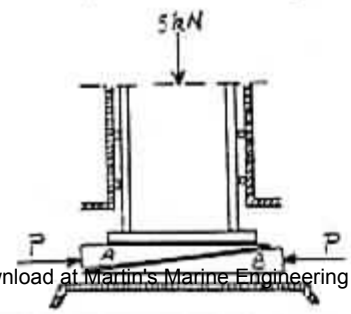


92. How much power can be transmitted by a V-belt between two 1.5 m diameter pulleys running at 250 rpm. Belt groove angle is 30° and belt CSA is 100 mm² density is 2.52 x 10³ kg/m³. Coefficient of friction between belt and pulley = 0.22

93. A mass of 2 tonnes is being lowered at 0.6 m/s by a 1200 mm² steel cable. When 15 m of the cable is out, the mass is brought to a sudden stop. Find the maximum stress on the cable and the maximum tension.
Ref DEC83

94. A police car equipped with a radar speed detecting device observes a motorist travelling at a speed of 120 km/h. The police car starts pursuing the motorist 30 seconds after the initial observation and accelerates to 160 km/h during a 20 second time interval. Assume both vehicles maintain their speeds on a straight unimpeded road.
1) Sketch a displacement-time graph of the events
2) Calculate the time and the distance traversed from the moment of the original observation until the chase ends.
Ans: 106 s
Ans: 5333 m
Ref FEB84

95. Two 5 degree wedges are used to adjust the position of a column under a vertical load of 5 kN. Determine the magnitude of the forces (P) required to raise the comumn if the coefficient of friction for all surfaces is 0.40



96. A hawser thrown from a ship to a pier is wrapped two full turns around a capstan. The tension in the hawser is 7500 N; by exerting a force of 150 N on its free end, a longshoreman can just keep the hawser from slipping. Determine the coefficient of friction between the hawser and the capstan

97. A solid steel cone, 450 mm diameter at the base and 600 mm perpendicular height, stands on its base on a level ground. Calculate the joules of work to tilt it until it is on the point of toppling over on to its side. The density of steel is 7.86 g/cm³ the position of the centre of gravity of a cone is at one-quarter of its height from the base
Ans: 295J

98. A pendulum whose length is 1.53 m oscillates 24 times per minute in a particular location. What is the acceleration of gravity there?

99. A mass of 25 kg is suspended from a spring which has a stiffness of 14 kN/m of extension. It vibrates freely with an amplitude of 12 mm. Find the periodic time, the velocity and acceleration when displaced 8 mm from the equilibrium position and time interval in passing from this position to the position of maximum displacement.
Ans: 0.266 s
Ans: 0.212 m/s
Ans: 4.88 m/s²
Ans: 0.356 s

100. A small plunger receives simple harmonic motion from a crank driving through a long connecting rod. The crank length can be set to give a long stroke of 450 mm or a short stroke of 150 mm. The change of speed is such that the product of crank speed and crank length is constant. The plunger has a mass of 25 kg and has to overcome a maximum resistance of 4.5 kN which on the long stroke, occurs at one-third of the stroke length from the beginning and, on the short stroke, at one-sixth of the stroke length from the end. The speed on the long stroke is 150 rev/min. Compare, for the positions of maximum resistance, the crank angles and the driving forces in the connecting rod.
Ans: 70°32' : 4.933 kN
Ans: 131°49' : 1.72 kN

101. A torsional pendulum consists of a wire 0.5 m long, 10 mm diameter, fixed at its upper end and attached at its lower end to a heavy disc having a moment of inertia of 0.06 kgm². The Modulus of Rigidity of the wire is 44 GN/m² . Find the frequency of the torsional oscillation of the disc. If the maximum displacement to one side of the rest position is 5° , find the maximum angular velocity and acceleration of the disc.
Ans: 6.04Hz
Ans: 3.31 rad/s
Ans: 125.5 rad/s