Mass

Mass of a body is the quantity of matter contained in a body. The unit of mass in F.P.S system is pound (lb), in C.G.S. system gram (gr) and in M.K.S and S.I systems kilogram (kg). 1ton which is 1000 kg is also used sometimes. The conversion factor is 1000. Three decimal places are shifted during conversion.E.g.1 ton = 1000 kg 1g = 1000mg.

m - mass of a body

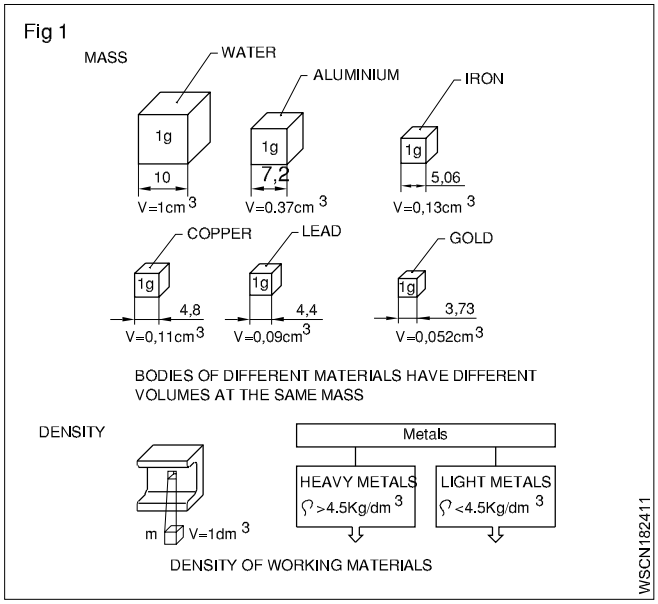
g - acceleration due to gravity in metre/sec^2 = 9.81 m/ sec^2

V - volume of the body

ρ - density (pronounced as `rho')

W or FG - weight or weight force

Mass (Fig 1)



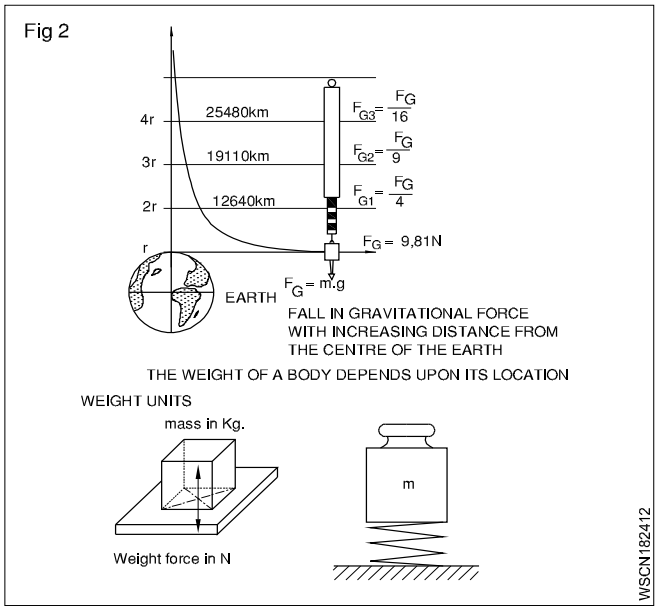
Density

Density is the mass of a body per unit volume. Hence its unit will be gr/cm^3 or kg/dm^3 or ton/m^3.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{v} = \rho$$

Weight (Fig 2)

Weight is the force with which a body is attracted by the earth towards its centre. It is the product of the mass of the body and the acceleration due to gravity. The weight of a body depends upon its location.



weight = *W* or *FG* = mass x gravitational force
= m x g

System	Absolute unit	Derived unit	Conversion
F.P.S. system	1 poundal	1 Lbwt	32.2 poundals (1 lb x 1 ft/sec^2 = 1 pound)
C.G.S. system	1 dyne 1 gr x 1 cm/sec^2	1 Gr.wt	981 dynes
M.K.S.	Newton	1 kg.wt	1 Newton =
S.I.system	Newton	Newton	1 kg x 1 m/sec^2

1 kg.wt = 9.81 Newton (approximately 10N) **1 Newton = 10^5 dynes.**

Difference between mass and weight

S. No	Mass	Weight
1	Mass is the quantity of matter in a body (ie) measurement of matter in a body	Weight is measure of amount of force acting on mass due to acceleration due to gravity
2	It does not depend on the position or space	It depends on the position, location and space
3	Mass of an object will not be zero	Weight of an object will be zero if gravity is absent
4	It is measured using by physical balance	It is measured using by spring balance
5	It is a scalar quantity	It is a vector quantity
6	When immersed in water mass does not change	When immersed in water weight will change
7	The unit is in grams and kilogram	The unit is in kilogram weight, a unit of force

Mass and weight are different quantities.

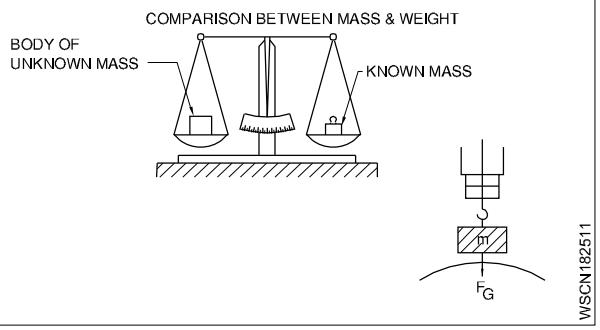
Mass of a body is equal to volume x density.

Weight force is equal to mass x acceleration due to gravity.

Weight , Density and Specific gravity

It is now seen that the mass of a substance is measued by its weight only without any reference to volume. But if equal weights of lead & aluminium, are compared the volume of lead is much smaller than volume of aluminium. So we can now say that lead is more dense than aluminium,. i.e In other words the density of lead is greater than aluminium. (Fig 3 & 4)

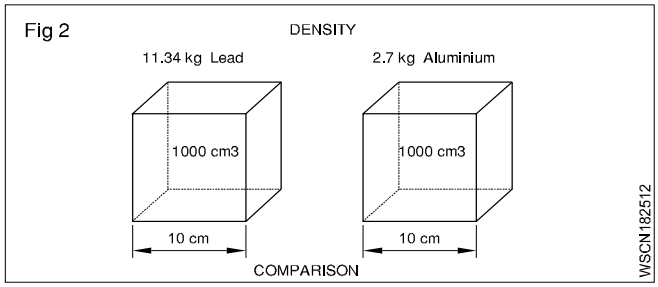
Fig 1



The relation of mass and volume is called density.

The density expresses the mass of volume E.g. 1 dm^3 of water has the mass of 1kg - thus the density of $1kg/dm^3$ (Fig 2)

Fig 2



Unit

The density is measured as below

MKS/SI= Kg/m^3, CGS - 1 gm/cm^3 FPS–lbs/c ft

	Solids	gm/cc^3	Liquids	gm/cc^3
1	Aluminum	2.7	Water	1.00
2	Lead	11.34	Petrol	0.71
3	Cast iron	6.8 to 7.8	Oxygen	1.43
4	Steel	7.75 to 8.05	Diesel Oil	0.83

The specific gravity of a substance is also called its relative density.

Formula

$$\text{Specific gravity (or) Relative density} = \frac{\text{Density of the substance}}{\text{Density of the water at } 4^\circ C}$$

$$= \frac{\text{Mass of any volume of a substance}}{\text{Mass of an equal volume of water at } 4^\circ C}$$

Comparison Between Density And Specific Gravity (Relative Density)

Density	Relative density or Specfiic gravity
Mass per unit volume of a substance is called its density Its unit is gm per cu cm; lbs per cu.ft and kg/cubic meter $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$	The density of substance to density of water at 4°C is its relative density It has no unit of measure-ment simply expressed in a number Relative density $= \frac{\text{Densityof the substance}}{\text{Densityof water at } 4^\circ C}$

	Solids	Sp.gy	Liquids	Sp.gy
1	Aluminium	2.72	Petrol	0.71
2	Lead	11.34	Battery acid	1.2 to 1.23
3	Cast iron	6.8 to 7.8	Water	1.00
4	Steel	7.82	Diesel Oil	0.83

From the above table, we can calculate the weight of any given volume of a substance (say Diesel oil) in any units provided we know the specific gravity of the substance. Also vice-versa for volume of density is known.

1 Calculate the mass in kg of a rectangular steel plate of dimensions 220 x 330 x 15 mm (Fig 1) (density of steel = 7.82 gm/cm$^{3)}$

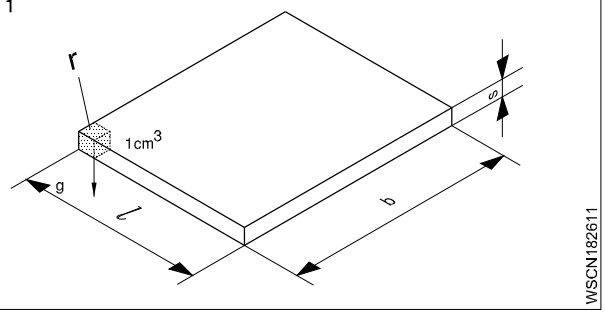
Mass = Volume x density

= 22 x 33 x 1.5cm^3 x 7.82 gm/cm^3

= 1089 cm^3 x 7.82 gm/cm^3

mass = 8.516 kg

Fig 1

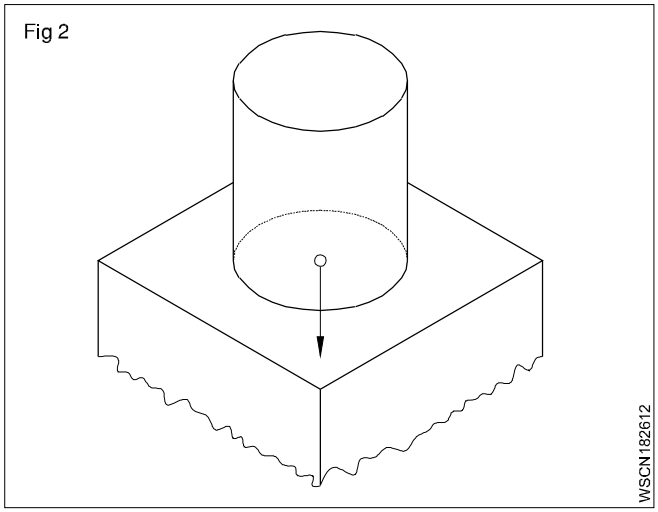


2 A storage container holds 250 litres of water. What weight in N will this amount of water exert on the surface on which it is standing?(Fig 2)

(1 litre of water = 1 kg of water)

Density of water 1 gm/cm^3 or 1 kg/dm^3

Fig 2



Acceleration due to gravity is taken as 10 metre/sec^2 (approximation).

Capacity = 250 litres = 250 dm^3 in volume.

Mass of water = volume x density of water

= 250 dm^3 x 1 kg/dm^3 = 250 kg

Weight extended = mass x acceleration due to gravity

= 250 kg x 10 metre/sec^2

= 2500 kg.metre/sec^2 = 2500 N($\because$ 1 kg.m/sec^2=1N)

3 A force of 15 dynes acting on a mass of `m' produces an acceleration of 2.5 cm/sec^2. Find the mass.

1 Gr. wt. = 981 dynes

$\therefore$ 15 dynes = $\frac{15}{981}$ Gr.wt

Force = m x acceleration produced by the force

$\therefore$ Gr.wt = mass x 2.5 cm/sec^2

$\therefore$ gr.cm/sec^2 = mass x 2.5 cm/sec^2

$\therefore$ mass = $\frac{15}{981 \times 2.5}$ grams = $\frac{\text{gm.cm/sec}^2}{\text{cm/sec}^2}$

mass = 0.00612 gram

4 A force of 2 N acts on a mass of 10 kg. Find the acceleration produced by the force on the mass.

Force = 2 N ($\because$ 1 N = 1kg.m/sec^2)

Force = mass x acceleration

$\therefore$ 2 kg.metre/sec^2 = 10 kg x acceleration produced

$\therefore$ 2 x 1 kg.metre/sec^2 = 10 kg x acceleration produced

$\therefore$ acceleration produced = $\frac{2}{10}$ metre/sec^2

= 0.2 metre/sec^2

5 Calculate the weight of a body having a mass of 1 kg if the acceleration due to gravity is 9.81 metres/sec^2

Weight force = mass x acceleration due to gravity

= 1 kg x 9.81 metres/sec^2

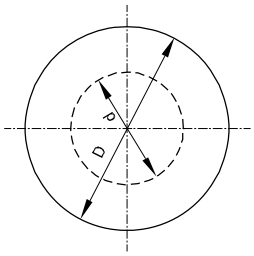
(1 kg.metre/sec^2 = 1 N)

$\therefore$ 9.81 kg metre/sec^2 = 9.81 N

In the examples solved the value of `g' is taken as 10 metre/sec^2, unless specifically mentioned otherwise.

- The outside and inside diametres of a hollow sphere are 150 & 70mm respectively. Calculate its mass if the density of material is 7.5 gm/cm^3. (Fig 3)

Fig 3



Mass = Volume x Density

= Volume x 7.5 gm/cm^3

D= 150 mm = 15cm R= 7.5 cm

d = 70mm = 7 cm r = 3.5 cm

$$\text{Volume} = \frac{4}{3}\pi\left(R^3 - r^3\right)\text{unit}^3$$

$$= \frac{4}{3}\pi(7.5^3 - 3.5^3)$$

$=1587.5\ cm^3$

Mass $= 1587.5\ cm^3 \times 7.5\ gm/cm^3$

$= 11906.6\ gm = 11.9kg$ say 12kg

6 A car has a mass of 800 kg. Find out its weight force (Take 9.81 m/sec^2)

($\because$ 1n = 1kg.m/sec^2)

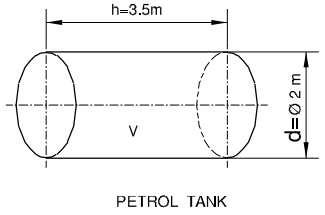
The Wt. force of a car=Mass of car x gravitational acceleration

= 800 x 9.81 N

= 7848 Newtons

7 A cylindrical tank 2m dia x 3.5 m deep is filled with petrol. Find the weight of petrol in Tonnes, Assume density of petrol 720 Kg/m^3.(Fig 4)

Fig 4



Volume of Tank

$$v = \pi r^2 h \text{ (or) } \frac{\pi d^2}{4} x h \text{ unit}^3 = \frac{\pi \times 2^2}{4} x 3.5\ m^3$$

3.14 x 3.5 m^3 = 10.99 m^3

Since 1 m^3 = 1000 litres

Volume of Tank = 10.99 x 1000 litres

Density of petrol = 720 Kg/m^3 .

Weight of Petrol in Kg =10.99x1000 litresx720Kg

= 720 x 10990 Kg

Weight of Petrol in Tonnes

(Metric Units) $= \frac{720X10990}{1000}$

Weight of Petrol = 7912.8 Tonnes

8 If the battery acid specific gravity is 1.3, and this is being filled up into a cylindrical tank. Find out its density.

(Density of water = 1000 gm/cm^3)

Specific gravity or Relative density

$$= \frac{\text{Density of the substance}}{\text{Density of water at } 4°c}$$

Now, density of battery acid

= Specific gravity x Density of water

= 1.3 x 1000 gm/cm^3

= 1300 gm/cm^3

Determination of specific gravity of a substance

The specific gravity of a substance may be determined by

1 Archemedies principle

2 Hydrometer

Archemedies Principle

Archemedies principle states that when a body is fully or partially immersed in a liquid, the amount of liquid displaced by the body is equal to the loss of weight of the body in the liquid.

Weight of a body in a liquid = total weight of the body

- weight of the liquid displaced by the body

This quantity if it is zero then the body will float. It is negative the body will rise up till the weight of liquid displaced by the immersed portion of the body is equal and equal to the weight of the body. If it is positive the body will sink. Specific gravity of solids soluble in water

$$= \frac{\text{weight of solid in air}}{\text{loss of weight of solid in water}}$$

specific gravity of solids soluble in water

$$= \frac{\text{weight of solid in air} \times \text{specific gravity of the liquid}}{\text{loss of weight of solid in which the solid is in solution}}$$

specific gravity of a liquid

$$= \frac{\text{loss weight of a solid in water}}{\text{loss of weight of the same solid in liquid}}$$

The solid chosen should be such that it is insoluble in both water and the liquid whose specific gravity is to be determined.

Example

1 An iron piece weighs 160 kgf in air and 133 kgf when it is fully immersed in water. Determine the volume and specific gravity of the iron piece.

Weight of the solid in air = 160 kgf
Weight of the solid in water = 133 kgf
$\therefore$ Loss of weight in water = 27 kgf

By Archemedies principle the loss of weight of a solid in water = volume of water displaced.
$\therefore$ Volume of water displaced = 27 cm^3

∴ Volume of the solid= 27 cm^3

$$\text{Density of the iron piece} = \frac{\text{mass of iron}}{\text{volume of the piece}}$$

$$= \frac{160}{160-133} = \frac{160}{27} = 5.93$$

$$\text{Specific gravity} = \frac{\text{Destiny of iron}}{\text{Destiny of water}} = \frac{5.93}{1} = 5.93$$

Specific gravity of iron piece = 5.93

2 A metal piece weighs 6.5 kgf in air and 3.5 kgf in water. Find its weight when it is fully immersed in a liquid whose specific gravity is 0.8 and also the S.G of the metal.

Weight of metal piece in air = 6.5 kgf
Weight of metal piece in water= 3.5 kgf
∴ Loss of weight in water = 3.00 kgf (6.5 - 3.5)
∴ Specific gravity of metal

$$\text{Loss of} = \frac{\text{weight of substance in air}}{\text{weight of substance in water}} = \frac{6.5\,kgf}{3kgf} = 2.166$$

By applying the principle of Archemedes the above results are derived.

By using a hydrometer also, the specific gravity of a liquid is determined. The most common type of hydrometer is the Nicholson's hydrometer which is a variable weight but constant immersion type.

Specific gravity of a liquid

$$\frac{\text{wt. of hydrometer+ wt. required to sink the hydrometer in the liquid to a fixed mark}}{\text{wt. of hydrometer+ wt. required to sink the hydrometer in water up to the same mark}}$$

Let the weight of the metal piece in the liquid = W

∴ loss of weight of the metal in the liquid = 6.5 kgf_W

$$\text{Specific gravity of the liquid} = \frac{\text{loss of weight in liquid}}{\text{loss of weight of water}}$$

$$\therefore 0.8 = \frac{6.5\,kgf - w}{3\,kgf}$$

∴ w = 6.5 kgf - 3 kgf x 0.8 = 4.1 kgf

∴ loss of weight of the metal in the liquid = 4.1 kgf.

3 A solid of wax weighs 21 kgf in air. A metal piece weighing 19 kgf in water is tied with the wax solid and both are immersed in water and the weight was found to be 17 kgf. Find the specific gravity of wax.

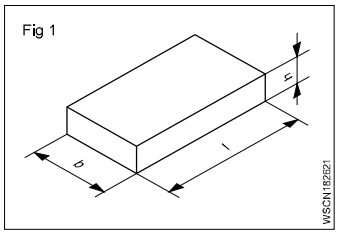
Weight of wax in air = 21 kgf
Weight of metal and wax in water = 17 kgf
Weight of metal piece only in water = 19 kgf
∴ weight of wax in water = (17 -19) kgf
= - 2 kgf
∴ loss of weight of wax in water = (21 - (-2)) kgf
= 23 kgf

$$\text{specific gravity of wax} = \frac{21\,kgf}{23\,kgf} = 0.913$$

Sl.No	Metal	Density gm/cc
1	Aluminium	2.7
2	Cast Iron	6.8 - 7.8
3	Copper	8.92
4	Gold	19.32
5	Iron	7.86
6	Lead	11.34
7	Nickel	8.912
8	Silver	10.5
9	Steel	7.75 - 8.05
10	Tin	7.31
11	Zinc	7.14
12	Diamond	3.51
13	Bismuth	9.78
14	Brass	8.47
15	Phosphrous Bronze	8.7 - 8.9
16	Ice	0.93
17	Air	0.0013
18	Mercury	13.56
19	Petrol	0.71
20	Diesel	0.83
21	Kerosene	0.78 - 0.81
22	Water	1.0

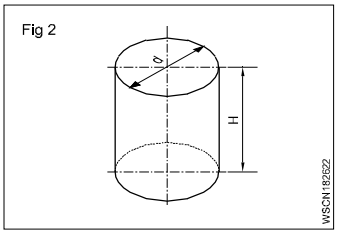
Assignment

1



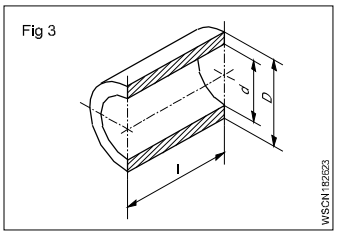
l = 1800 mm
b = 65 mm
h = 12 mm
ρ = 7.85 g/cm³
m = _____ kg

2



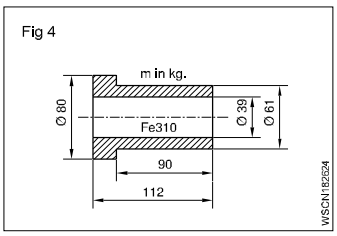
Capacity = 36 litres
d = 32 cm
H = _____ cm

3



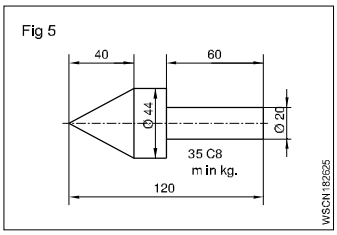
D = 74 mm
d = 68 mm
l = 115 mm
ρ = 8.6 gm/cm³
m = _____ gms

4



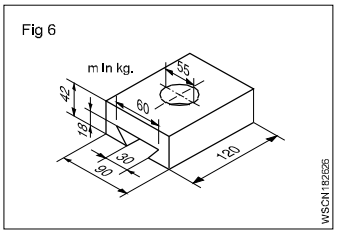
D_1 = 80 mm
D_2 = 61 mm
d = 39 mm
L = 112 mm
l = 90 mm
ρ = 7.85 gm/cm³
m = _____ kg

5



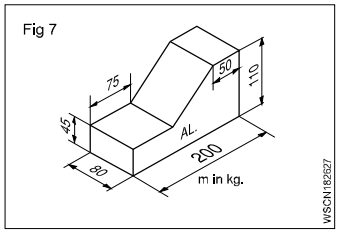
D = 44 mm
d = 20 mm
L = 120 mm
l_1 = 60 mm
l_2 = 40 mm
ρ = 7.85 gm/cm³
m = _____ kg

6



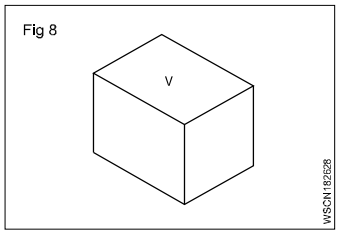
L = 120 mm
B = 90 mm
b_1 = 60 mm
b_2 = 30 mm
d = 55 mm
H = 42 mm
h = 18 mm
ρ = 7.85 gm/cm³
m = _____ kg

7



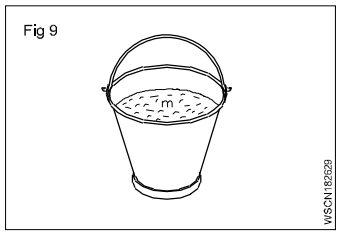
L = 200 mm
l_1 = 75 mm
l_2 = 50 mm
B = 80 mm
H = 110 mm
h = 45 mm
ρ = 2.7 gm/cm³
m = _____ kg

8



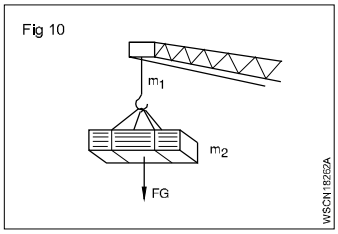
V = 320 cm³
ρ = 8.9 gm/cm³
g = 9.80665 metre/ sec²
m = _____ kg
FG = _____ N

9



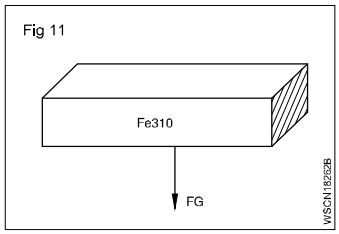
Capacity = 35 litres
g = 10 metres/sec²
FG = _____ N

10



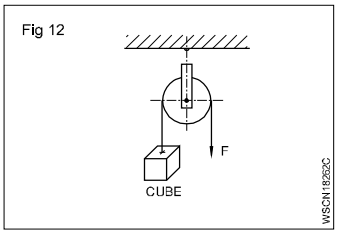
(m_1) mass of chain = 150 kg
Total FG = 8 KN
Load = _____ N
mass m_2 = _____kg

11



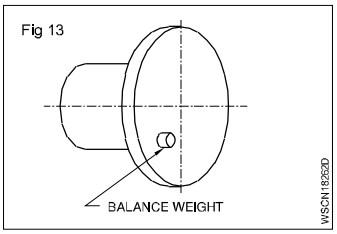
W (FG) = 22.5 N
V (volume) = _____

12



F = 250 d N
side of cube = _____ mm
(cubical counter weight balances `F')

13

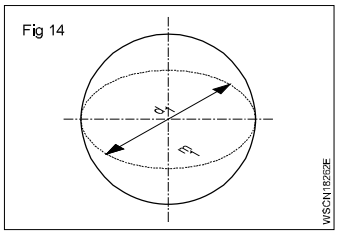


unbalanced load in the set up = 16 cN

ø of balancing weight = 20 mm

l of balancing weight = _____ mm

14



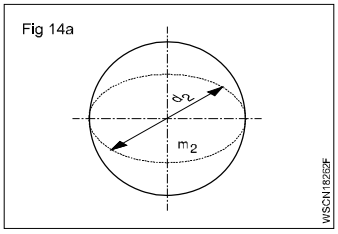
d_1 = 40 mm

$m_1 = 9 \times 10^{-2}$ kg

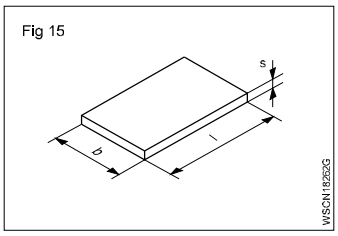
$r_1 = r_2$

d_2 = 60 mm

FG_2 = _____ N



15

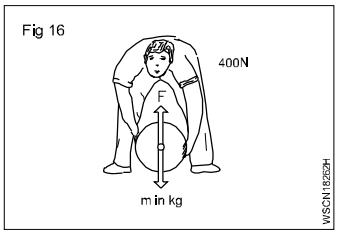


l x b = 1 m^2

FG = 7.85×10^{-2} kN

s = _____ mm

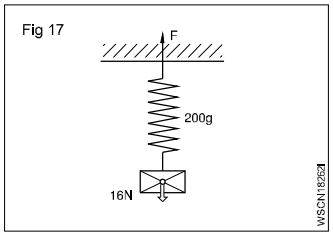
16



F = 400 N

m = _____ kg

17

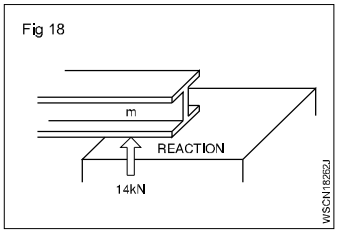


m_1 = 200 gms

FG = 16 N

F = _____ dN

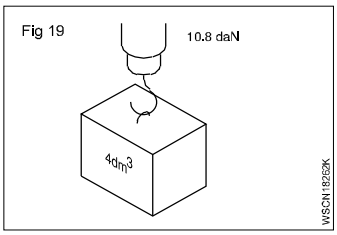
18



R = 14 kN

m = _____ kg

19

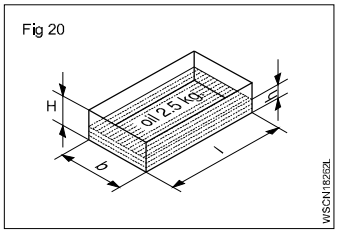


V = 4 dm^3

FG = 10.8 daN

ρ = _____ gm/cm^3

20



l = 500 mm

b = 300 mm

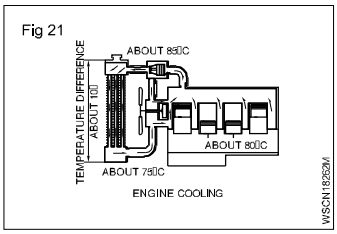
H = 250 mm

ρ of oil = 0.9 gm/cm^3

m = 2.5 kg

h = _____ mm

21



Engine cooling

Data given

Water in Radiator = 10 litres

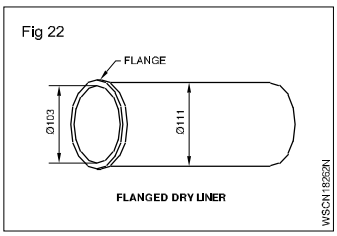
Find

Mass of water = _____kg

(Assume 1 litre = dm^3 in volume)

Density of water = 1 kg/dm^3

22



Cylinder Liner Dimension

Data given

OD = 111 mm

ID = 103 mm

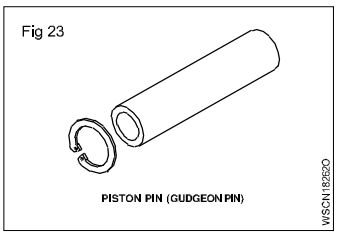
Length = 240 mm

Material = C.I

Density of C.I = 7.259 gm/cm^3

Find its mass___ in kg

23



Gudgeon Pin (Solid)

Data given

Dia = 200 mm

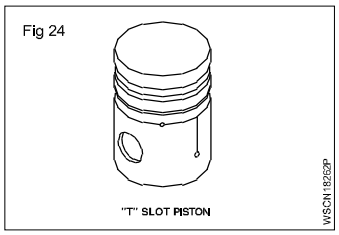
Length = 70 mm

Material = M.S

Density = 7.85 gm/cm^3

Find its mass = ___gm

24



Data given

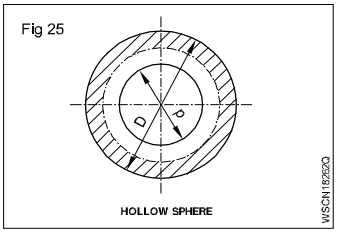
Dia = 80 mm

Length = 100 mm

Density of Aluminum = 2.7 g/cm^3

Find its Mass _____ in kg

25



Hollow sphere (Cast Brass)

Data given

O.D = 150 mm

I.D = 120 mm

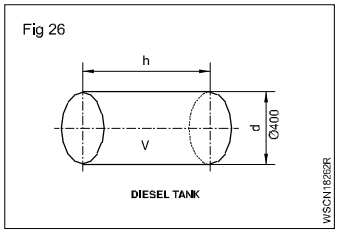
Density of Brass = 6.89 gm/cc

Use Vol = $(\frac{4}{3}\pi\ (R^3)^3)$

Find

Mass of Hollow sphere = _____ kg

26



Diesel Tank

Data given

Diameter = 400 mm

Depth of filling (h) = 600 mm

Spongy of oil = 0.8

Density of water = 1000 kg/m^3

Find

Mass of oil in Tank = _____ in kg

27 Definition

Define the following term

a Mass

b Weight

c Density

d Specific gravity

28 Conversion of vehicle weights

Take g = 10 m/sec^2

	Weight force	Mass
a	480 Newton	_____
b	14800 N	_____
c	2000 N	_____
d	7000 N	_____

29 Coversion of mass of vehicle

Take g = 9.81 m/sec^2

	Mass of Vehicle	**Its weight**
a	1200 kg	_____N
b	800 kg	_____N
c	700 kg	_____N
d	900 kg	_____N

30 Fill up the blanks

Comparison of Metals & Liquids

	Material	**Sp.gy**	**Density**
a	Lead	11.34	_____
b	Copper	8.92	_____
c	Cast Iron	7.20	_____
d	Petrol	0.71	_____
e	Diesel	0.83	_____
f	Sulphuric Acid	1.84	_____

31 Fill in the blanks with correct statement in a & b

a The density of water - 1000 kg/m3 specific gravity of nitric acid = 1.2. The density of nitric acid = _____

b	Material	Density	Specific gravity
i	Water	1000 kg/m^3	_____
ii	Aluminium	2.7 g/cm^3	_____
iii	Iron	8 g/cc	_____
iv	Copper	8.7 g/cc	_____

c Mass of a body = Volume x _____

d Weight force = Mass x _____

e Give abbreviation for

i Mega newton _____

ii Kilo newton per square metre _____

f 1 litre of water = _____kg.