MASS, WEIGHT & DENSITY

Mass and weight

Gravitational fields

Density

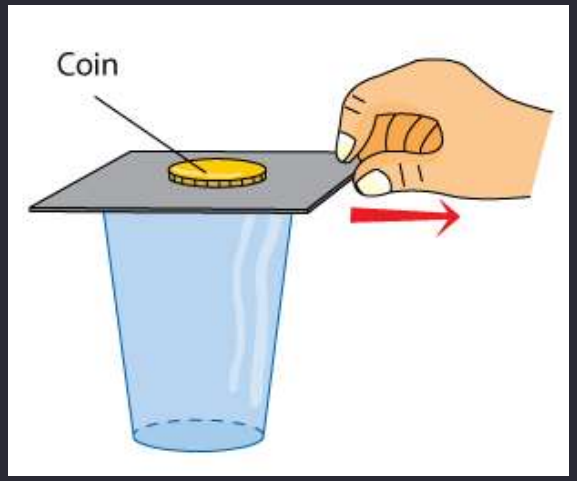
MASS & WEIGHT

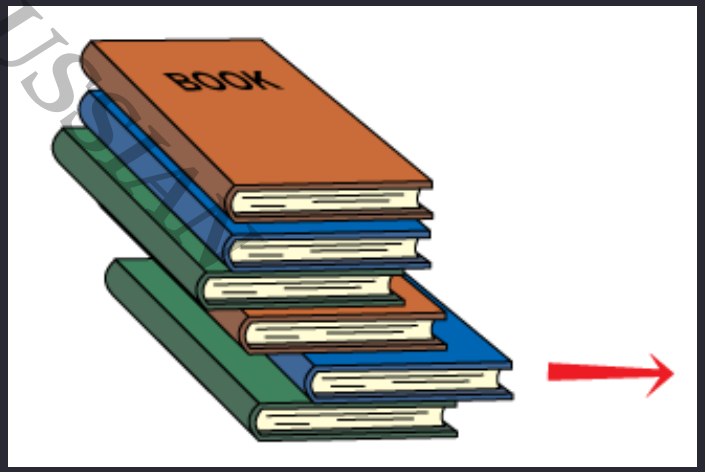
State that mass is a measure of the amount of substance in a body.

State that mass of a body resists change from its state of rest or motion.

MASS & INERTIA

- The **mass** of an object is a measure of the amount substance in the object.
- All bodies with mass posses a property known as **inertia**.
- The **inertia** of an object is the reluctant of the object to change either its state of rest, or if it is moving, its motion in a straight line.





INERTIA

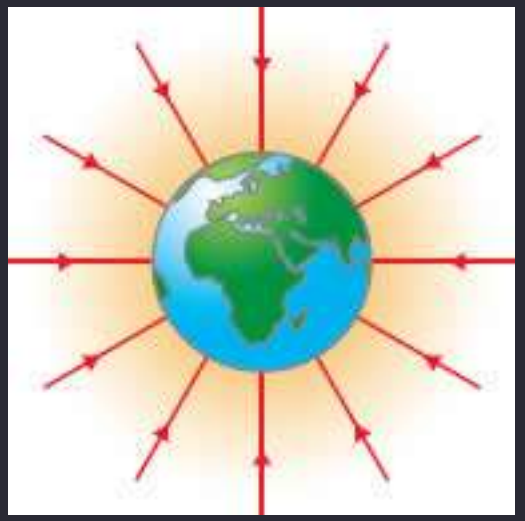
- The **greater** the mass of a body the **greater** will be its inertia.

GRAVITATIONAL FIELDS

State that a gravitational field is a region in which a mass experiences a force due to gravitational attraction.

GRAVITATIONAL FIELD

- **Gravitational field** is a region in which the mass of an object experiences a force due to gravitational attraction.
- Any object placed around the Earth experiences a force pulling it towards the Earth.
- The force is stronger on the surface of the Earth and gets weaker as we go farther away.



MASS & WEIGHT

Calculate weight from the equation weight = mass x gravitational field strength.

Explain that weights, and therefore masses, may be compared using a balance.

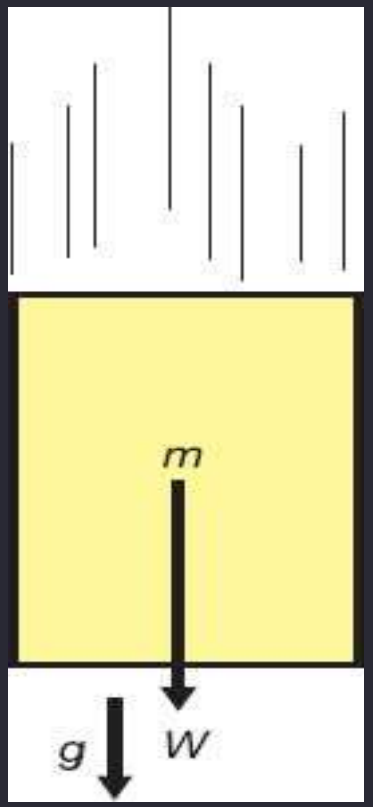
Describe how to measure mass and weight by using appropriate balances.

WEIGHT

- The **weight** of an object is the force of gravity acting upon the object.

weight = mass × acceleration due to gravity

$$w = mg$$



- It is measure in newtons (N)
- The **greater** the mass of an object, the **greater** is its weight.
- Acceleration due to gravity has the same numerical value as the gravitational field strength.

MEASURING MASS & WEIGHT

triple beam balance

electronic balance

Spring balance

PROBLEM SOLVING

1. A hammer has a mass of 1 kg. What is its weight (i) on Earth (ii) on the Moon (iii) in outer space.
2. The weight of an object on Earth is 55 N. The gravitational field strength on Earth is 10 N/kg. What is the mass of the object.
3. A man has a mass of 70 kg. What is his weight on Jupiter where the field strength is 26 N/kg.

EXAMPLE

4. A spacecraft travels from Earth to Mars, where the gravitational field strength near the surface is 3.7 N/kg. The spacecraft is carrying a probe which has a mass of 100 kg when measured on Earth. Assuming that g = 10 N/kg on Earth.

   a) What is the probe's weight on Earth?

   b) What is the probe's mass in space?

   c) What is the probe's mass in Mars?

   d) What is the probe's weight on Mars?

   e) When the probe is falling, near the surface of Mars, what is its acceleration?

5. A Saturn V Moon rocket has a mass at lift-off of 3.0×10^6 kg. The thrust at lift-off is 3.3×10^7 N. Find:

   a) the weight of the rocket on Earth

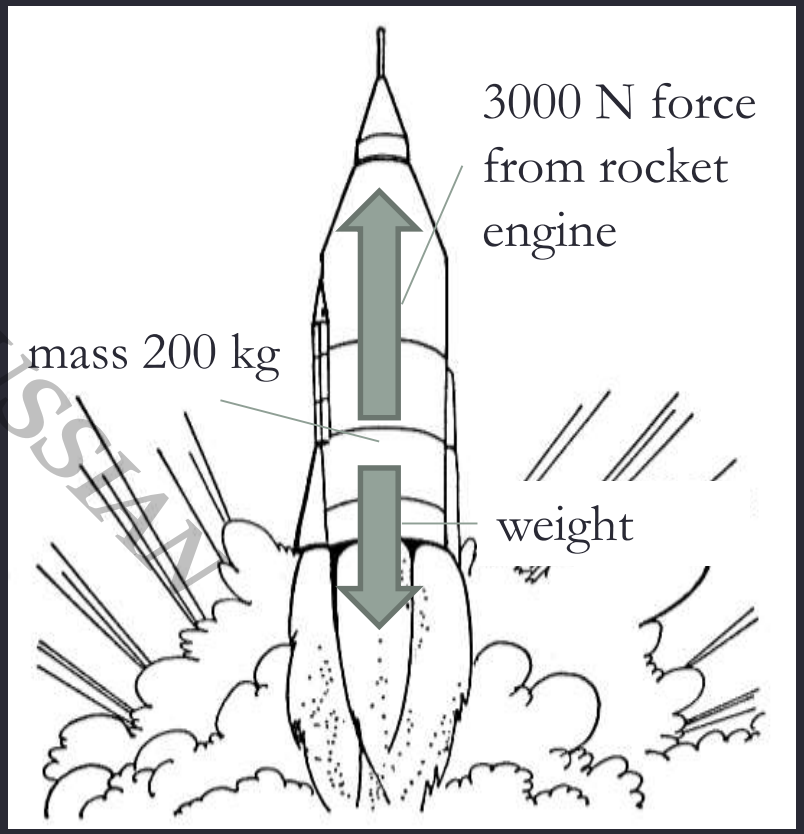
   b) the resultant (unbalanced) force at lift-off

   c) the acceleration at lift-off

   d) the apparent weight of the rocket in orbit

EXAMPLE

6. What is the acceleration of the rocket on the right?



MASS & WEIGHT

	Mass	Weight
1	is the amount of substance in the body	is the force of gravity acting on the body
2	is constant at any location	depends on acceleration due to gravity at the location
3	is a scalar quantity	is a vector quantity
4	is measured in kilograms	is measured in newtons
5	is measured using a beam balance or electronic balance (pan balance)	is measured using a spring balance
6	can never be zero	can be zero

1. The inertia of a body is its resistance to changes in motion. Which property is a measure of the body's inertia?

   A. its density

   B. its mass

   C. the height of its sides

   D. the size of its base

2. Which statement about the mass of a falling object is correct?

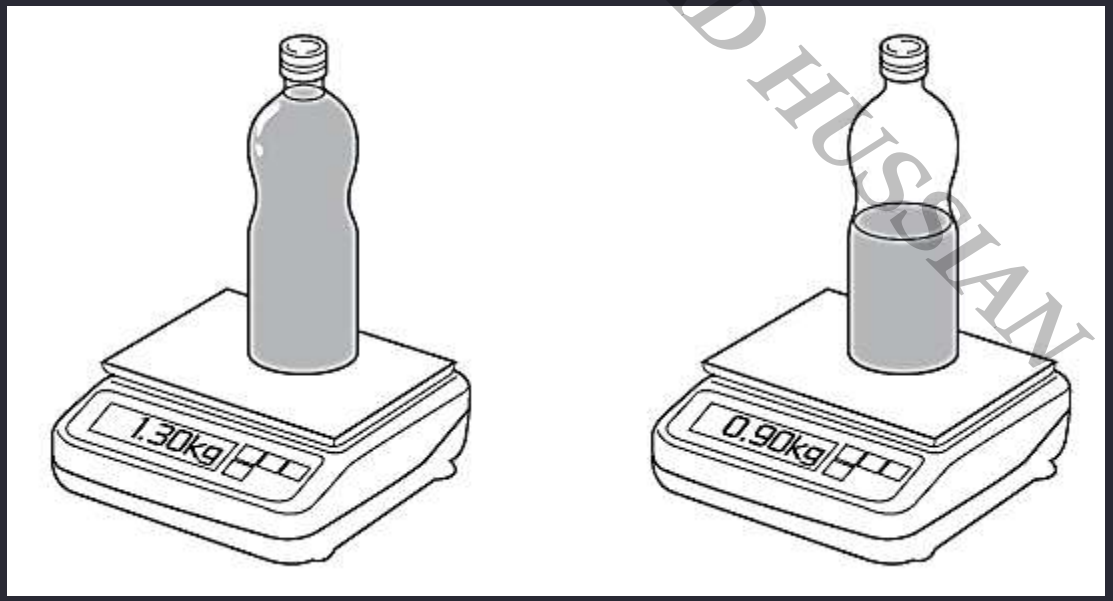
   A. It decreases as the object falls.

   B. It is equal to the weight of the object.

   C. It is measured in newtons.

   D. It stays the same as the object falls.

3. The mass of a full bottle of cooking oil is 1.30 kg.
4. When exactly half of the oil has been used, the mass of the bottle plus the remaining oil is 0.90 kg.



What is the mass of the empty bottle?

A. 0.40 kg
B. 0.50 kg
C. 0.65 kg
D. 0.80 kg

4. What is the gravitational force that the Earth exerts on an object?

   A. the density of the object

   B. the mass of the object

   C. the volume of the object

   D. the weight of the object

5. What is the meaning of the weight of an object?

   A. the density of the material from which it is made

   B. the force exerted on it by gravity

   C. the mass of the matter it contains

   D. the pressure it exerts on the floor

6. Which relationship defines gravitational field strength?

   A. mass x 10

   B. mass x weight

   C. mass / weight

   D. weight / mass

7. What are the correct units for force and for weight?

	force	weight
A	kg	kg
B	kg	N
C	N	kg
D	N	N

D

8. A body of mass 10 kg falling freely in the gravitational field close to the Moon's surface has an acceleration of 1.6 m/s^2.
9. What is the gravitational field strength on the Moon?

   A. 0 N/kg

   B. 1.6 N/kg

   C. 10 N/kg

   D. 16 N/kg

9. An object that has a mass of 15 kg on the Earth is taken to the Moon.
10. The gravitational field strength on the Earth is 10 N/kg and on the Moon is 1.6 N/kg.
11. What are the mass and the weight of the object on the Moon?

	mass/kg	weight/N
A	15	24
B	15	150
C	24	15
D	150	24

A

10. A person of weight 600 N at the bottom of a mountain climbs to the top. The gravitational field strength changes from 10.00 N/kg at the bottom to 9.97 N/kg at the top. His mass is unchanged as he climbs.
11. What are his mass and his weight at the top of the mountain?

	mass at top of mountain/kg	weight at top of mountain/N
A	60.0	598
B	60.0	600
C	60.1	598
D	60.1	600

A

11. At a point on the surface of the Earth, the gravitational field strength is 9.8 N/kg.
12. Which pair of values for mass and weight are correct for an object placed at this point?

	mass/kg	weight/N
A	9.8	10
B	10	9.8
C	10	98
D	98	10

C

12. The table shows the weight of a 10 kg mass on each of five planets.

planet	weight of a 10kg mass/N
Mercury	40
Venus	90
Earth	100
Mars	40
Jupiter	250

1. On which planets would an astronaut have a smaller weight than on Earth?

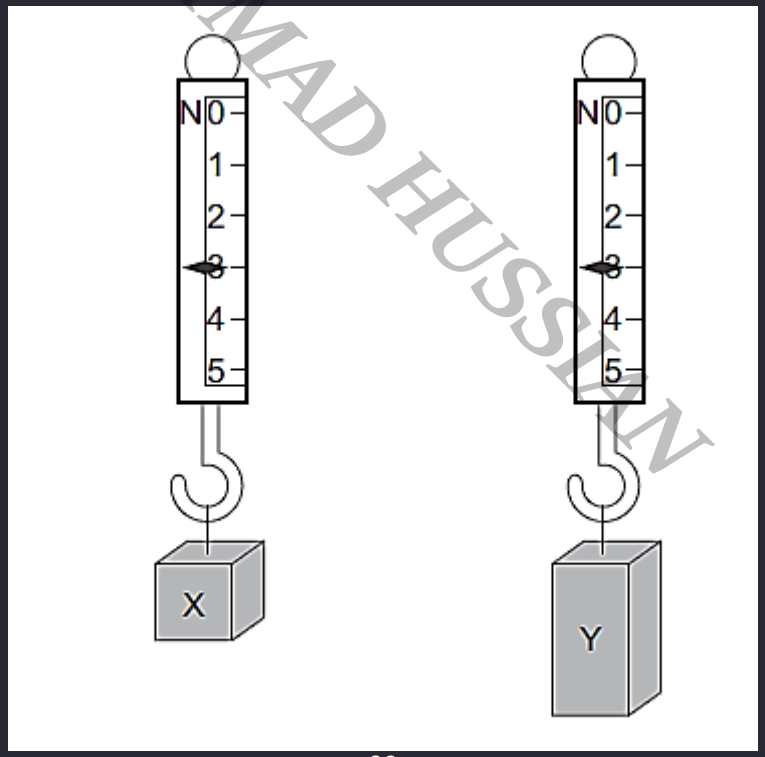
A. Mercury, Mars and Jupiter

B. Mercury, Venus and Mars

C. Mercury, Venus and Jupiter

D. Venus, Mars and Jupiter

13. Two blocks of metal X and Y hang from spring balances as shown in the diagram.



1. What does the diagram show about X and Y?

A. They have the same mass and the same volume but different weights.

B. They have the same mass and the same weight but different volumes.

C. They have the same mass, the same volume and the same weight.

D. They have the same weight and the same volume but different masses.

14. A passenger is sitting in an aeroplane, which takes off and climbs to 10000 m.
15. During this time, what happens to the mass and to the weight of the passenger?

	mass	weight
A	decreases	decreases
B	increases	increases
C	unchanged	decreases
D	unchanged	increases

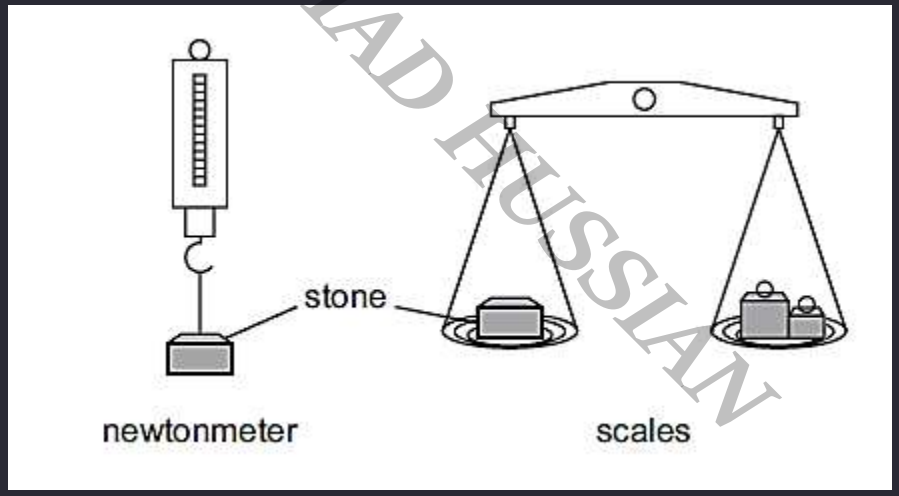
C

15. The force of gravity acting on an astronaut in an orbiting spacecraft is less than when she is on the Earth's surface.
16. Compared with being on the Earth's surface, how do her mass and weight change when she goes into orbit?

	mass in orbit	weight in orbit
A	decreases	decreases
B	decreases	unchanged
C	unchanged	decreases
D	unchanged	unchanged

C

16. A stone is weighed using a newtonmeter (spring balance) and a pair of scales (pan balance).



1. This experiment is repeated on the Moon.
2. Are the readings for each balance the same or different when taken on Earth and on the Moon?

	reading on newtonmeter	reading on scales
A	different	different
B	different	same
C	same	different
D	same	same

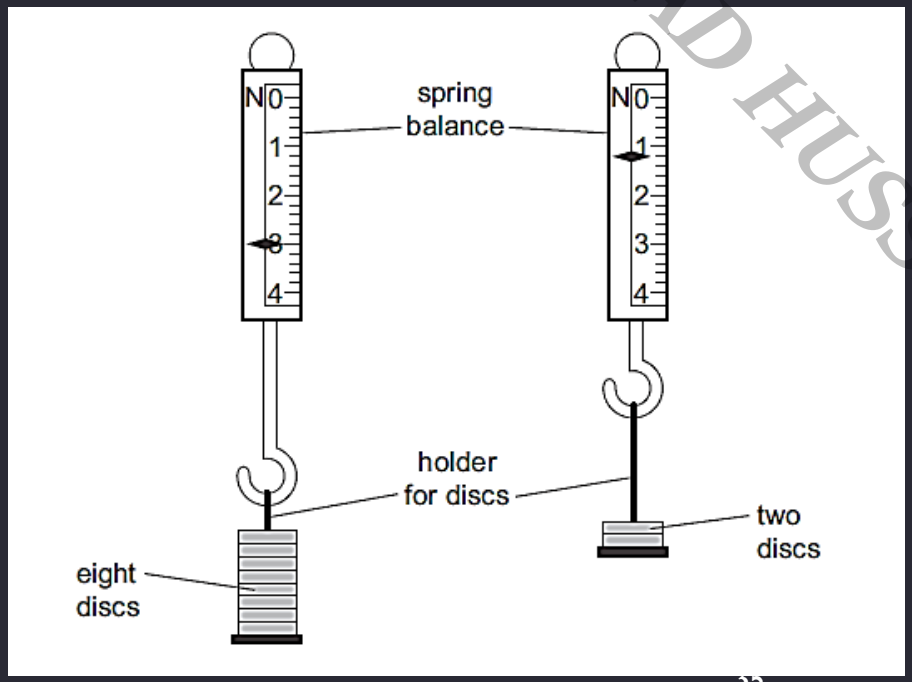
B

17. In a laboratory on Earth, balances show that an object has a mass of 2 kg and a weight of 20 N.
18. The same balances and object are then taken to the Moon, where the gravitational field strength is less than on the Earth.
19. Are the mass and weight of the object the same, or less, than before?

	mass	*weight*
A.	less	less
B.	less	same
C.	same	less
D.	same	same

C

18. The reading on a spring balance with a holder and eight identical discs is 3.0 N.
19. Six discs are removed and the reading becomes 1.2 N.



What is the weight of one disc?

A. 0.2 N
B. 0.3 N
C. 0.5 N
D. 0.6 N

19. Which statement about the masses and weights of objects on the Earth is correct?

A. A balance can only be used to compare weights, not masses.

B. Heavy objects always have more mass than light ones.

C. Large objects always have more mass than small ones.

D. Mass is a force but weight is not.

20. Which statement is correct?

A. The mass of a bottle of water at the North Pole is different from its mass at the Equator.

B. The mass of a bottle of water is measured in newtons.

C. The weight of a bottle of water and its mass are the same thing.

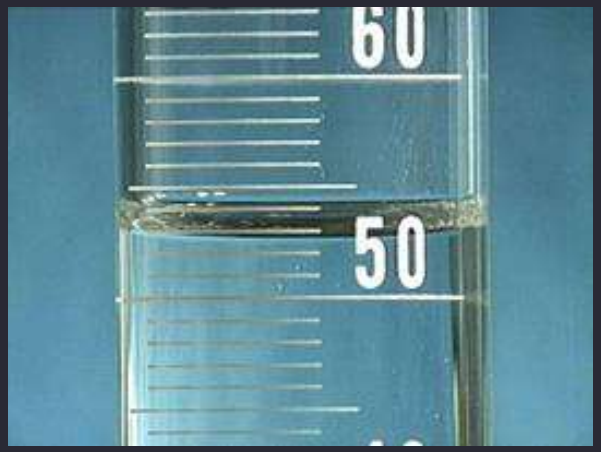
D. The weight of a bottle of water is one of the forces acting on it.

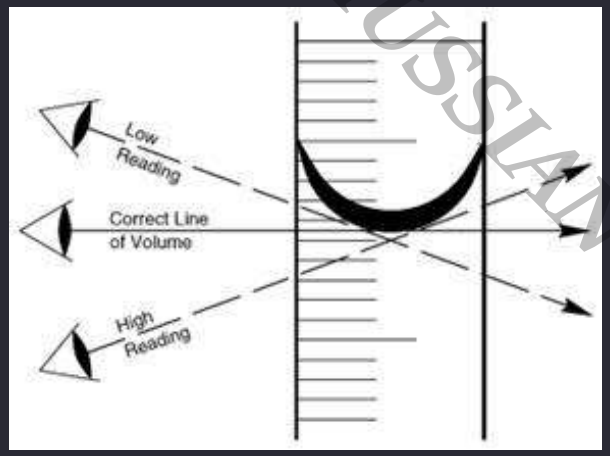
DENSITY

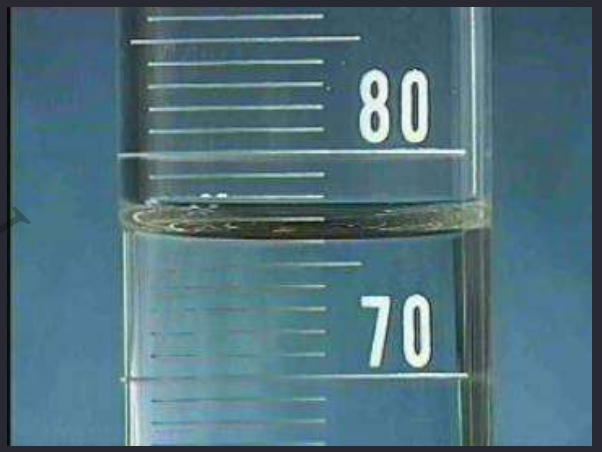
Describe how to use a measuring cylinder to measure the volume of a liquid or solid.

VOLUME OF LIQUID

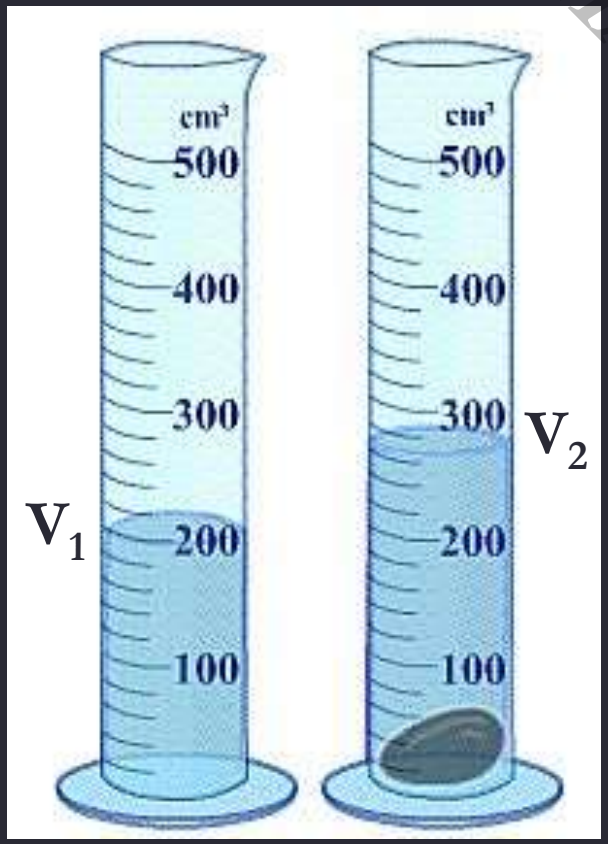
- We use a **graduated cylinder** to find the volume of liquid.
- Just pour the liquid in and read the measurement on the side of the cylinder (in ml or cm^3).







DISPLACEMENT METHOD



- Put some water in a graduated cylinder and write down the volume of the water, V_1.
- Drop in your object and get the new volume, V_2.
- Subtract the water's original volume from the water + object volume, $V_2 - V_1$

DENSITY

Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in water (volume by displacement).

EXPERIMENTAL PROCEDURE

1. Aim: To determine the density of liquid

   Apparatus

   Procedure

   Calculation

   Precautionary Measure

APPARATUS

1. Electronic balance
2. Measuring cylinder

PROCEDURE

1. Measure the mass of the empty measuring cylinder, m_1. Take the average reading.
2. Fill the measuring cylinder with water.
3. Measure the mass of the water inside the measuring cylinder, m_2. Take average reading.
4. Read the volume of water on the measuring cylinder.

CALCULATION

1. Mass of the water = $m_2 - m_1$
2. Density of water = mass of water / volume of water

PRECAUTIONARY MEASURE

1. Avoid parallax error when reading the measuring cylinder
2. To reduce wind interference
3. Always re-zero the electronic balance
4. Take average reading of the mass

EXPERIMENTAL PROCEDURE

2. Aim: To determine the density of regular solid

   Apparatus

   Procedure

   Calculation

   Precautionary Measure

APPARATUS

1. Solid cube
2. Electronic balance
3. 30 cm rule

PROCEDURE

1. Measure the mass of the cube using electronic. Take average reading.
2. Using the rule measure all the length of the side (length, breadth & height).

CALCULATION

1. Volume of cube = length x breadth x height
2. Density = mass / volume

PRECAUTIONARY MEASURE

1. Avoid parallax error
2. Check zero error
3. Reduce wind interference
4. Take average reading of mass and length

EXPERIMENTAL PROCEDURE

3. Aim: To determine the density of irregular solid

   Apparatus

   Procedure

   Calculation

   Precautionary Measure

APPARATUS

1. Plasticine
2. Electronic balance
3. Measuring cylinder

PROCEDURE

1. Measuring the mass of the plasticine using the electronic balance. Take average reading
2. Fill the measuring cylinder with water. Take the initial reading of the meniscus, V_1
3. Submerged the plasticine into the cylinder. Take the new reading of the meniscus, V_2

CALCULATION

1. Volume of plasticine = $V_2 - V_1$
2. Density of plasticine = mass / volume

PRECAUTIONARY MEASURE

1. All plasticine must submerge
2. Not to splash out the water when inserting the plasticine inside the cylinder
3. Take average reading of mass

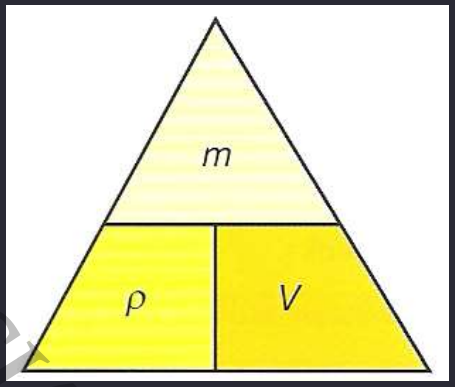
DENSITY

Define density and recall and use the formula *density = mass/volume*

DENSITY

- The **density** of a substance is defined as its mass per unit volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$



- The SI unit for density is **kilogram per cubic metre** (kg/m^3) but other units like gram per cubic centimeter (g/cm^3) is also commonly used.

$$1\ g/cm^3 = 1000\ kg/m^3$$

PROBLEM SOLVING

1. A cylinder has a base of area 100 cm^2 and contains water to a height of 10 cm. A piece of rock mass 600 g is lowered into the water and the water level rises to a height of 12 cm.

   a. What is the volume of the piece of rock?

   Volume of Rock = Base Area x Height displaced

   Volume of Rock = 100 cm^2 x 2 cm^2

   Volume of Rock = 200 cm^3

PROBLEM SOLVING

1. A cylinder has a base of area 100 cm^2 and contains water to a height of 10 cm. A piece of rock mass 600 g is lowered into the water and the water level rises to a height of 12 cm.

   b. Calculate the density of the rock.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{600\ \text{g}}{200\ \text{cm}^3}$$

$$\text{Density} = 3\ \text{g/cm}^3$$

PROBLEM SOLVING

2. The density of a solid is 4 g/cm^3. What is the volume of 200 g of the solid.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$4\ \text{g/cm}^3 = \frac{200\ \text{g}}{\text{volume}}$$

$$\text{volume} = \frac{200}{4}$$

$$\text{volume} = 50\ \text{cm}^3$$

PROBLEM SOLVING

3. An empty measuring cylinder has a mass of 200 g. A liquid is poured into the measuring cylinder until the liquid is at the 80 cm^3 mark. The total mass is now 272 g. What is the density of the liquid in g/cm^3?

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{72\ \text{g}}{80\ \text{cm}^3}$$

$$\text{Density} = 0.9\ \text{g/cm}^3$$

PROBLEM SOLVING

4. A sample of ethanol has a volume of 240 cm^3. Its mass is found to be 190.0 g. What is the density of ethanol.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{190\ \text{g}}{240\ \text{cm}^3}$$

$$\text{Density} = 0.792\ \text{g/cm}^3$$

PROBLEM SOLVING

5. Calculate the density of mercury if 500 cm^3 has a mass of 6.60 kg. Give your answer in g/cm^3.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{6600\ \text{g}}{500\ \text{cm}^3}$$

$$\text{Density} = 13.2\ \text{g/cm}^3$$

PROBLEM SOLVING

6. A steel block has a mass of 40 g. It is in the form of a cube. Each edge of the cube is 1.74 cm long. Calculate the density of the steel.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{40}{1.74 \times 1.74 \times 1.74}$$

$$\text{Density} = 7.59 \text{ g/cm}^3$$

PROBLEM SOLVING

7. What is the volume of a storage tank which will hold 3200 kg of petrol? Density of petrol = 800 kg/m^3.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$800\ \text{kg/m}^3 = \frac{3200\ \text{kg}}{\text{volume}}$$

$$\text{volume} = \frac{3200}{800}$$

$$\text{volume} = 4\ \text{m}^3$$

PROBLEM SOLVING

8. A small rectangular block of steel measures 2 cm by 4 cm by 5 cm and has a mass of 312 g. Calculate its density

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{312\ \text{g}}{2 \times 4 \times 5}$$

$$\text{Density} = \frac{312}{40}$$

$$\text{Density} = 7.8\ \text{g/cm}^3$$

PROBLEM SOLVING

9. The mass of a small metal statue is found to be 90 g. A measuring cylinder is filled with water to the 82 cm^3. The statue is lowered into the measuring cylinder and the water rises to the 91 cm^3. What is the density of the metal.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Density} = \frac{90\ \text{g}}{9\ \text{cm}^3}$$

$$\text{Density} = 10\ \text{g/cm}^3$$

PROBLEM SOLVING

10. What mass of lead has the same volume of 1600 kg of petrol? Density of petrol = 800 kg/m^3 & density of lead = 11400 kg/m^3.

$$\text{Density of petrol} = \frac{\text{mass of petrol}}{\text{volume of petrol}}$$

$$800\ \text{kg/m}^3 = \frac{1600\ \text{kg}}{\text{volume of petrol}}$$

$$\text{volume of petrol} = \frac{1600}{800} = 2\ \text{m}^3$$

$$\text{volume of petrol} = \text{volume of lead}$$

$$\text{Density of lead} = \frac{\text{mass of lead}}{\text{volume of lead}}$$

$$11400\ \text{kg/m}^3 = \frac{\text{mass of petrol}}{2\ \text{m}^3}$$

$$\text{mass of lead} = 11400 \times 2$$

$$\text{mass of lead} = 22800\ \text{kg}$$

PROBLEM SOLVING

11. An engineer needs to know the mass of steel girder which is 20 cm long, 0.1 m wide and 0.1 m high. (Density of steel = 8000 kg/m^3)

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$8000 = \frac{\text{mass}}{0.2 \times 0.1 \times 0.1}$$

$$\text{mass} = 8000 \times 0.2 \times 0.1 \times 0.1$$

$$\text{mass} = 16\ \text{kg}$$

PROBLEM SOLVING

12. A contractor wants to load some bricks into his van. There are 1000 bricks, and when stacked neatly they measure 2 m by 1 m by 1 m.

a) What is the volume of the stack?

$$\text{volume of stack} = 2 \times 1 \times 1$$

$$\text{volume of stack} = 2\ \text{m}^3$$

b) If the density of brick is 2500 kg/m^3, what is the mass of the stack?

$$\text{density of stack} = \frac{\text{mass of stack}}{\text{volume of stack}}$$

$$2500 = \frac{\text{mass of stack}}{2}$$

$$\text{mass of stack} = 2500 \times 2 = 5000\ \text{kg}$$

PROBLEM SOLVING

12. A contractor wants to load some bricks into his van. There are 1000 bricks, and when stacked neatly they measure 2 m by 1 m by 1 m.

    c) If his van's maximum load is 1000 kg, how many bricks can he load?

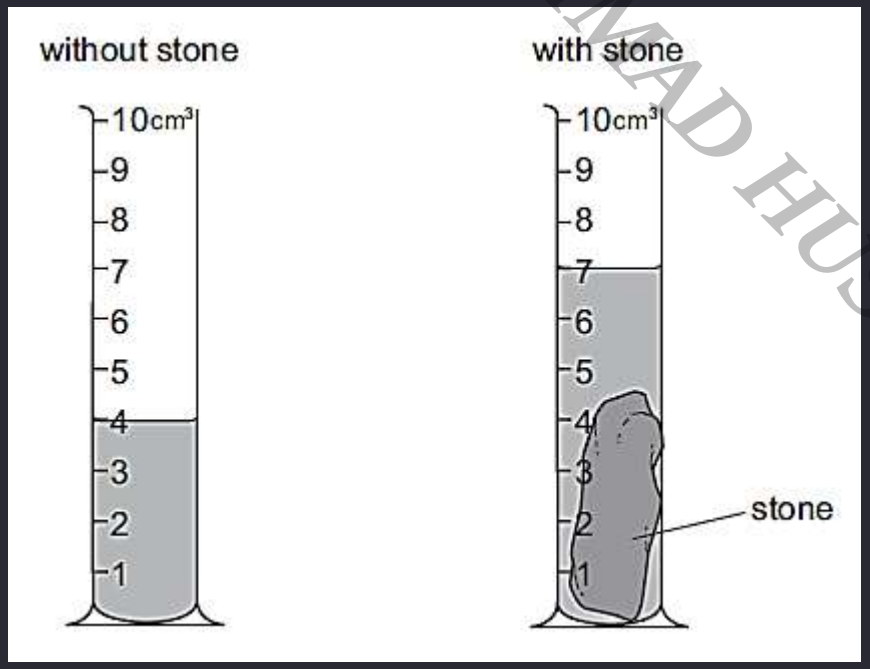
$$1000 \text{ bricks} = 5000 \text{ kg}$$

$$\text{how many bricks} = 1000 \text{ kg}$$

$$\text{no. of bricks} = \frac{1000 \times 1000}{5000}$$

$$\text{no. of bricks} = 200 \text{ bricks}$$

1. The diagrams show an experiment to determine the volume of a stone.



What is the volume of the stone?

A. 3 cm^3
B. 4 cm^3
C. 7 cm^3
D. 11 cm^3

2. Which of the following is a unit of density?

   A. cm^3/g

   B. g/cm^2

   C. g/cm^3

   D. kg/m^2

3. Which items of apparatus are required to determine the density of a liquid?

   A. balance and measuring cylinder

   B. balance and thermometer

   C. metre rule and measuring cylinder

   D. metre rule and thermometer

4. A student is trying to find the density of water and of a large, regularly shaped concrete block.
5. Which apparatus is needed to find the density of both the water and the concrete block?

   A. balance, clock, measuring cylinder

   B. balance, clock, ruler

   C. balance, measuring cylinder, ruler

   D. clock, measuring cylinder, ruler

5. A student needs to find the density of a cubic block of wood.
6. Which two pieces of apparatus should she use?

A. balance and metre rule

B. balance and thermometer

C. measuring cylinder and metre rule

D. measuring cylinder and thermometer

6. A student does an experiment to estimate the density of an irregularly-shaped stone.
7. Which items of equipment are needed?

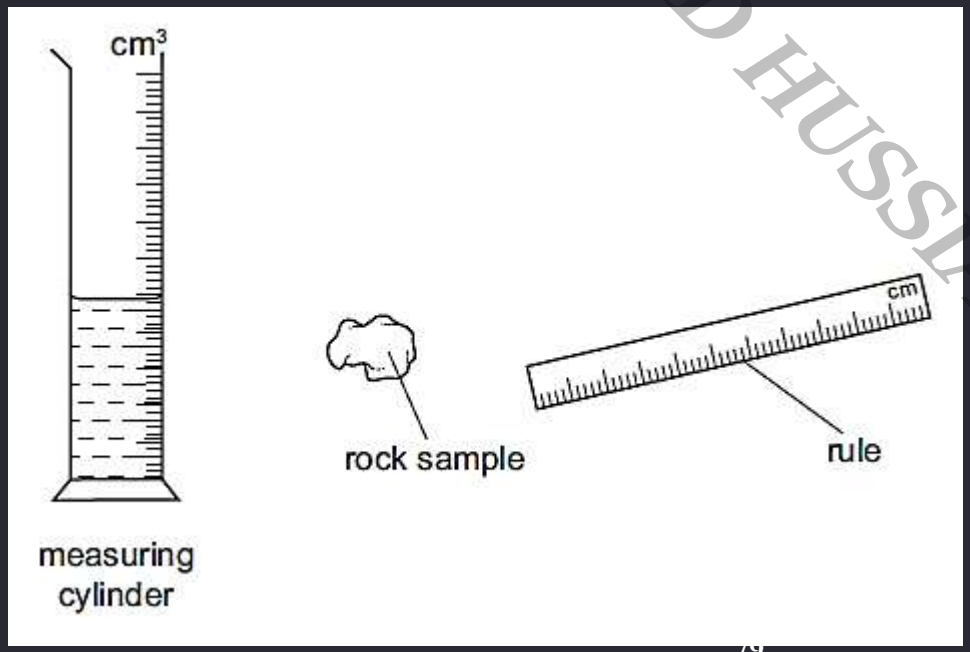
   A. a balance and a measuring cylinder containing water

   B. a balance and a ruler

   C. a ruler and a measuring cylinder containing water

   D. only a measuring cylinder containing water

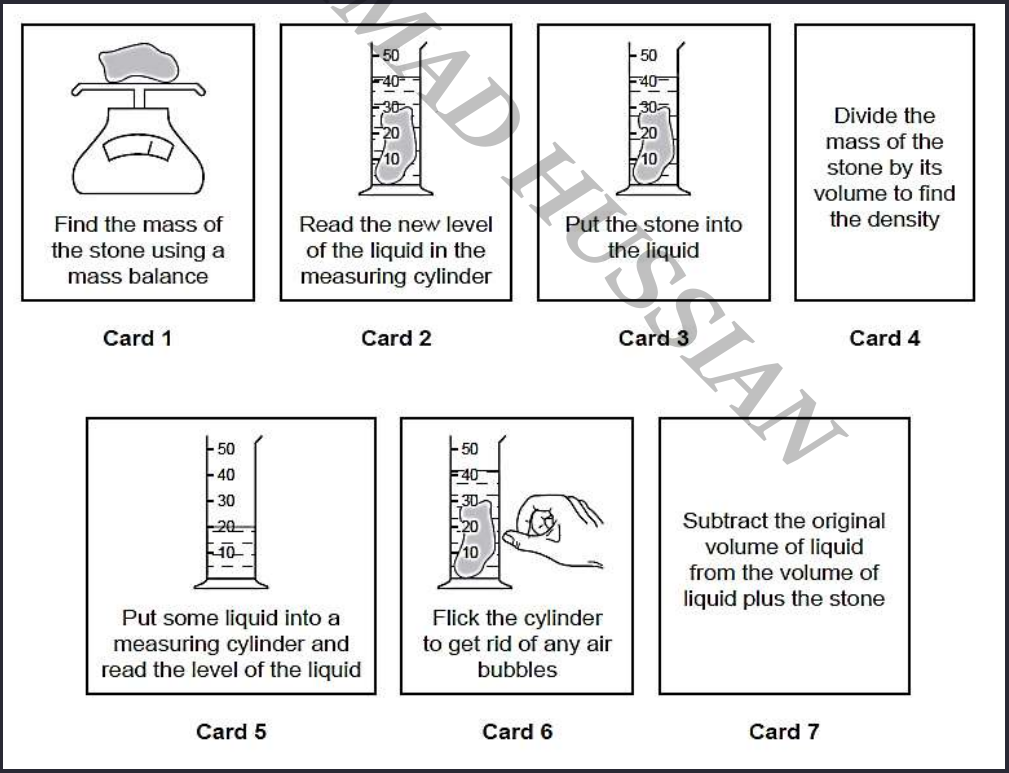
7. A scientist needs to determine the volume of a small, irregularly shaped rock sample. Only a rule and a measuring cylinder, partially filled with water, are available.



To determine the volume, which apparatus should the scientist use?

A. both the measuring cylinder and the rule
B. neither the measuring cylinder nor the rule
C. the measuring cylinder only
D. the rule only

8. A student is trying to find the density of a stone, but he has mixed up the instruction cards.



What order should the cards be in?

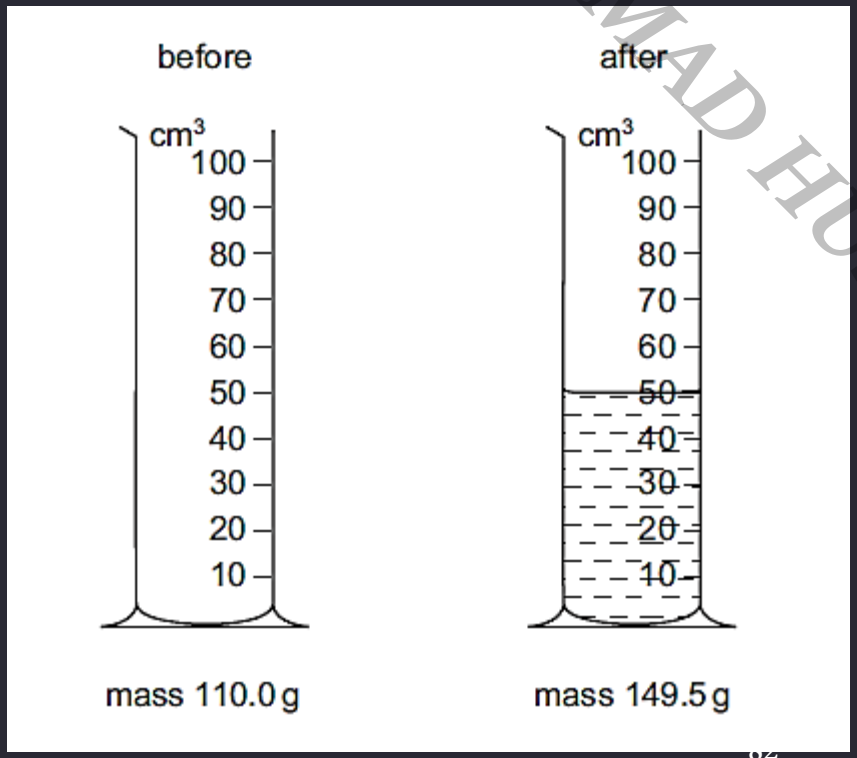
A. 5 → 3 → 6 → 2 → 1 → 4 → 7

B. 1 → 5 → 3 → 6 → 2 → 7 → 4

C. 5 → 6 → 3 → 2 → 1 → 7 → 4

D. 1 → 4 → 5 → 3 → 6 → 2 → 7

9. The mass of a measuring cylinder is measured before and after pouring a liquid into it.



What is the density of the liquid?

A. 0.79 g/cm^3
B. 1.3 g/cm^3
C. 1.4 g/cm^3
D. 2.2 g/cm^3

10. A metal drum has a mass of 200 kg when empty and 1000 kg when filled with 1.0 m^3 of methylated spirit.

    What is the density of methylated spirit?

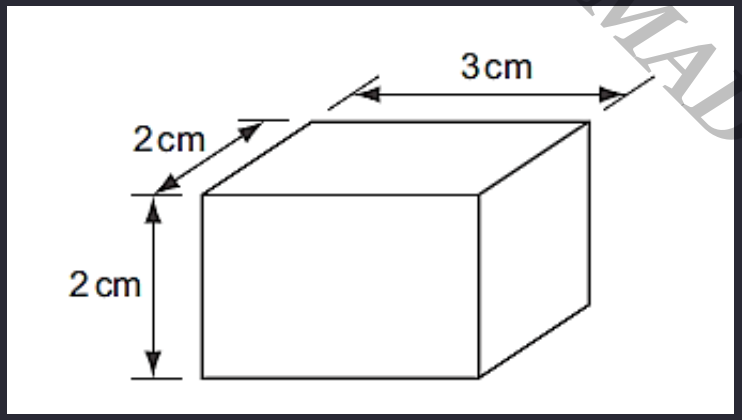
    A. 0.0050 kg/m^3

    B. 0.11 kg/m^3

    C. 800 kg/m^3

    D. 1000 kg/m^3

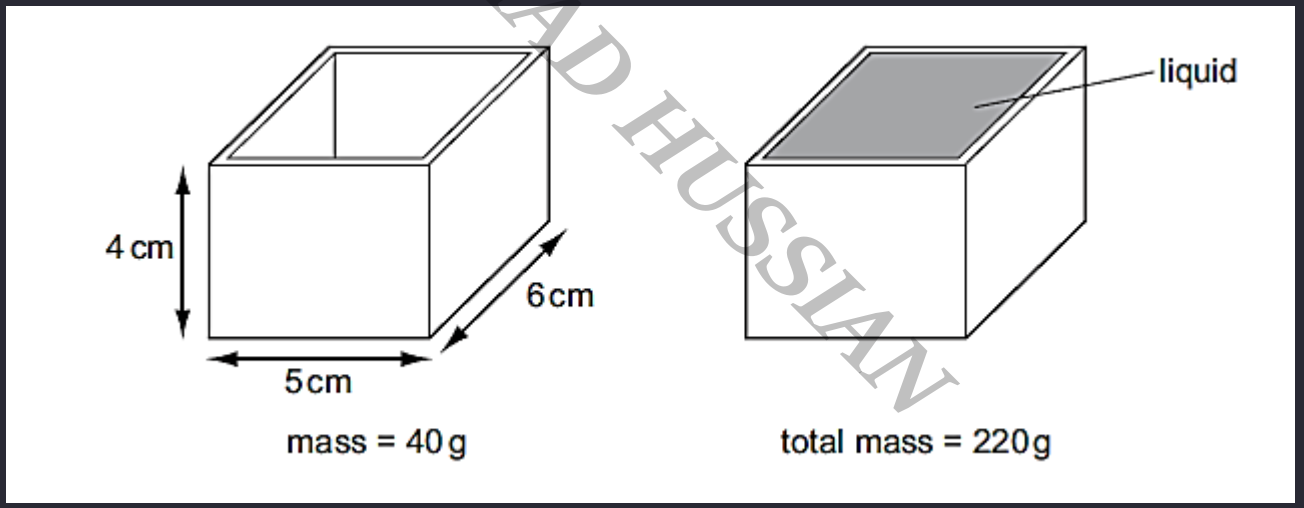
11. The diagram shows a rectangular block of density 2 g/cm^3.



What is the mass of the block?

A. 2 g
B. 6 g
C. 14 g
D. 24 g

12. The diagrams show a rectangular box with inside measurements of 5 cm × 6 cm × 4 cm.



The box has a mass of 40 g when empty. When filled with a liquid, it has a total mass of 220 g.

What is the density of the liquid?

A $\frac{220}{(5\times6\times4)}\ g/cm^3$

B $\frac{(220-40)}{(5\times6\times4)}\ g/cm^3$

C $\frac{(5\times6\times4)}{220}\ g/cm^3$

D $\frac{(5\times6\times4)}{(220-40)}\ g/cm^3$

B

13. A room measures 4.0 m × 3.0 m × 2.0 m. The density of the air in the room is 1.3 kg/m^3.

    What is the mass of air in the room?

    A. 0.054 kg

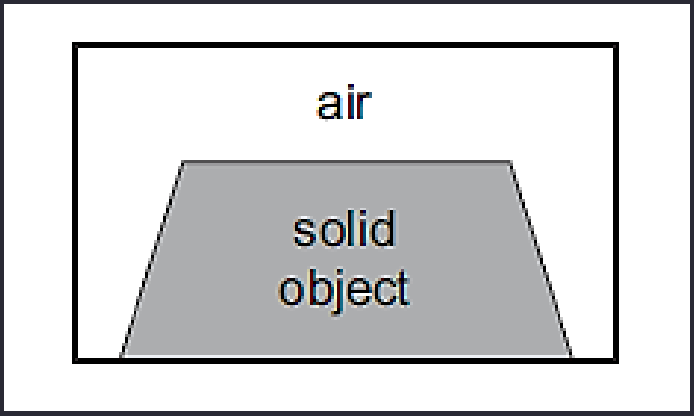
    B. 18 kg

    C. 24 kg

    D. 31 kg

14. A box has an internal volume of 1000 cm^3. When a solid object is placed in the closed box, the volume of air in the box is 520 cm^3.

    The density of the object is 8.00 g/cm^3.

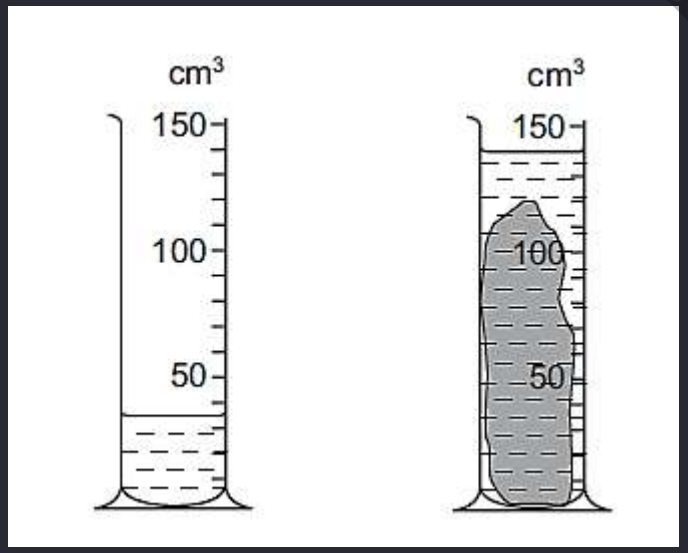


What is the mass of the object?

A. 60.0 g
B. 3840 g
C. 4160 g
D. 8000 g

15. A lump of metal has a mass of 210 g. It is lowered into a measuring cylinder containing water.

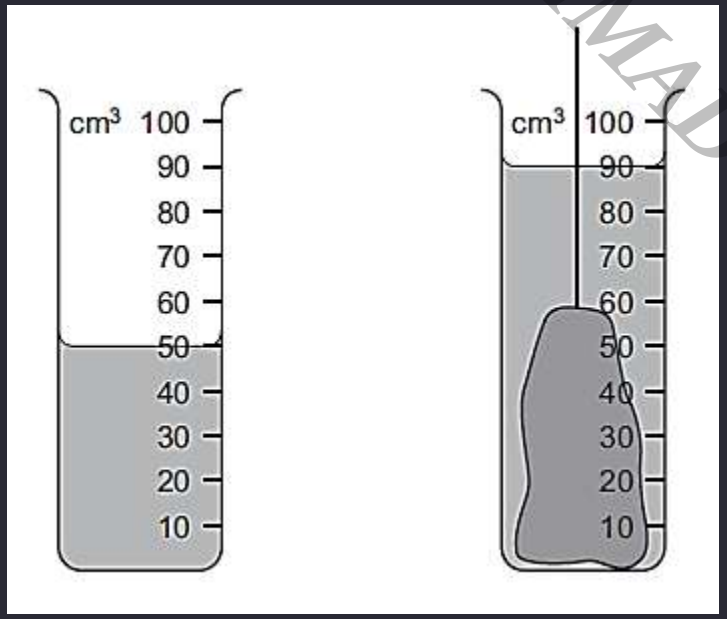
    The level of the water rises from 35 cm^3 to 140 cm^3.



What is the density of the metal?

A. 0.67 g/cm^3
B. 1.5 g/cm^3
C. 2.0 g/cm^3
D. 6.0 g/cm^3

16. An object of mass 100 g is immersed in water as shown in the diagram.



What is the density of the material from which the object is made?

A. 0.4 g/cm^3
B. 0.9 g/cm^3
C. 1.1 g/cm^3
D. 2.5 g/cm^3

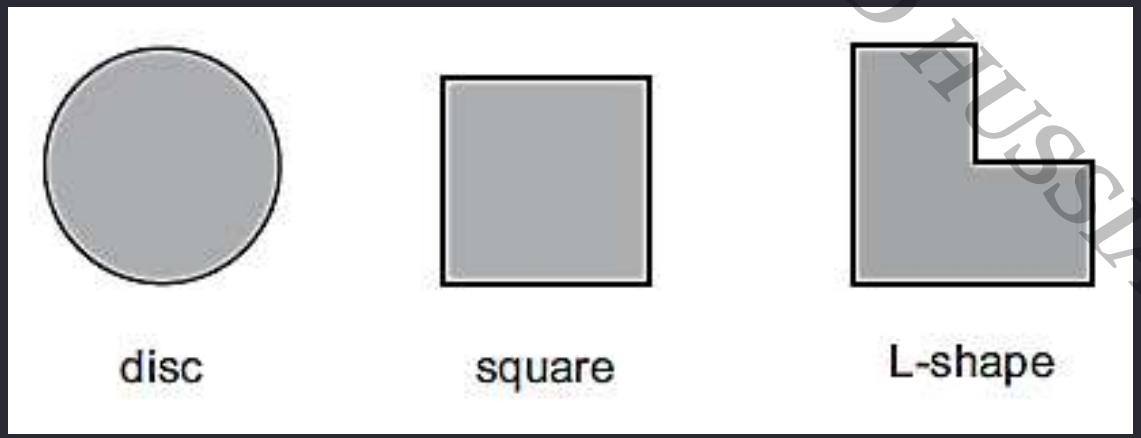
17. A measuring cylinder contains 118 cm^3 of water. When a small object is fully immersed in the water, the reading goes up to 132 cm^3. The object has a mass of 42 g.

What is the density of the object?

A $\frac{14}{42}$ g/cm^3 B $\frac{42}{14}$ g/cm^3 C $\frac{42}{118}$ g/cm^3 D $\frac{132}{42}$ g/cm^3

B

18. Three objects are cut from the same sheet of steel. They are different shapes but they all have the same mass.

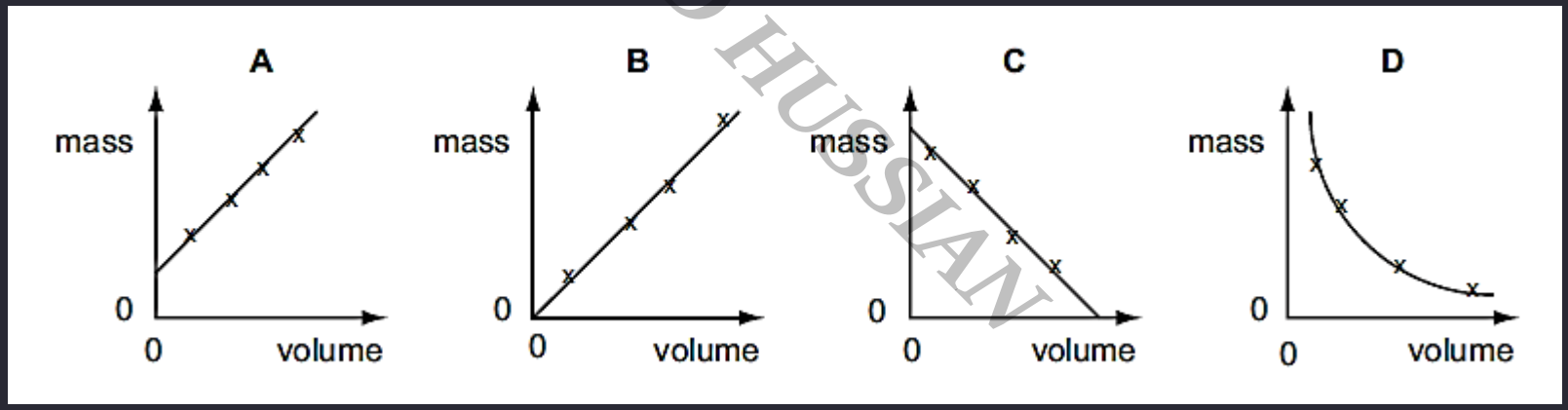


Which object has the greatest density?

A. the disc
B. the L-shape
C. the square
D. they all have the same density

19. Some students measure the masses and the volumes of different sized samples of a type of wood.

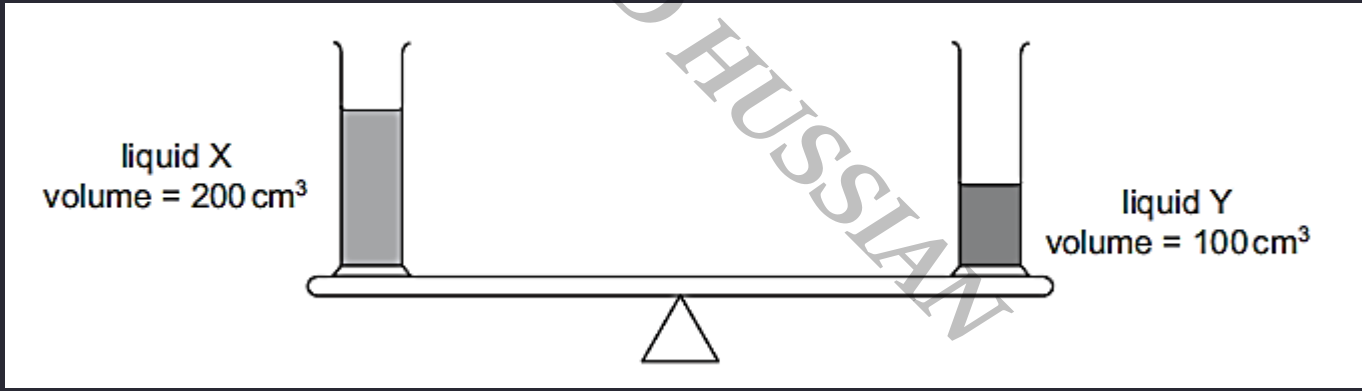
    Which graph shows their results?



B

20. Two identical measuring cylinders containing different liquids are placed on a simple balance.

    They balance as shown.



How does the density of X compare with the density of Y?

A density of X = $\frac{1}{2}$ × density of Y

B density of X = density of Y

C density of X = 2 × density of Y

D density of X = 4 × density of Y

A