Physical Quantities and Measurement Technique

G1 | Ji Yutong | 15/02/2023

How do we describe physical world?

Physics Quantity

a physical property of a material or system that can be quantified by measurement

Common physical quantities?

length, area, volume; temperature, time, mass, velocity, force

Classification?

Scalar: only has magnitude

Vector: has magnitude AND direction

How to express a physical quantity?

measurement: number + unit

7 basic quantities & SI units

7 Base Quantity	SI Unit	
	Name	Symbol
Mass		
Length		
Time		
Electric current		
Temperature		
Luminous intensity		
Amount of substance		

7 basic quantities & SI units

7 Base Quantity	SI Unit	
	Name	Symbol
Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous intensity	Candela	cd
Amount of substance	Mole	mol

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Exam-style questions

Which is a pair of SI base units?

A	ampere	joule
B	coulomb	second
C	kilogram	kelvin
D	metre	newton

Exercise

Exercise:

1.a Guess the mass of an apple, an adult, the Earth, express them in SI unit.

1.b Guess the size of an atom, the height of an adult, a school building, the circumference of the Earth, express them in SI unit.

Powers of ten shorthand — standard notation

A neat way of writing numbers

$$9000 = 9 \times 10 \times 10 \times 10 = 9 \times 10^3$$

$$900 = 9 \times 10 \times 10 \qquad = 9 \times ?$$

$$90 = 9 \times 10 \qquad = 9 \times 10^1$$

$$9 = 9 \times 1 \qquad = 9 \times ?$$

$$0.9 = 9/10 \qquad = 9 \times 10^{-1}$$

$$0.09 = 9/100 \qquad = 9 \times ?$$

$$0.009 = 9/1000 \qquad = 9 \times ?$$

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$$90 = 9 \times 10 = 9 \times 10^1$$

$$9 = 9 \times 1 = 9 \times 10^0$$

$$0.9 = 9/10 = 9 \times 10^{-1}$$

$$0.09 = 9/100 = 9 \times 10^{-2}$$

$$0.009 = 9/1000 = 9 \times 10^{-3}$$

$1000 = 10^3$

$100 = 10^2$

$10 = 10^1$

$1 = 10^0$

$0.1 = 10^{-1}$

$0.01 = 10^{-2}$

$0.001 = 10^{-3}$

Standard Notation

Exercise:1.c:

1000 =

10 =

1 =

0.000005 =

Prefix - length

Definition of meter(m):

The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.

Submultiples

1 nanometre(nm) = 10^{-9}m

1 micrometre(um) = 10^{-6}m

1 millimetre(mm) = 10^{-3}m

1 centimetre(cm) = 10^{-2}m

1 decimetre(dm) = 10^{-1}m

Multiples

1 kilometre(km) = 10^{3}m

1 megameter(Mm) = 10^{6}m

1 gigametre(Gm) = 10^{9}m

Prefix - length

Generally speaking,

kilo(k) $\longleftrightarrow$

mega(M) $\longleftrightarrow$

giga(G) $\longleftrightarrow$?

milli(m) $\longleftrightarrow$

micro(μ) $\longleftrightarrow$

nano(n) $\longleftrightarrow$

Prefix - length

Generally speaking,

kilo(k) ⟷	10^3
mega(M) ⟷	10^6
giga(G) ⟷	10^9
milli(m) ⟷	10^{-3}
micro(μ) ⟷	10^{-6}
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Exercise: 1.e

1 kilogram(kg) = g

1 milliAmpere(mA) = A

1 millisecond (ms) = s

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Exercise: 1.e

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Exam-style questions

Which product-pair of metric prefixes has the greatest magnitude?

A. centi × mega

B. nano × kilo

C. micro × giga

D. milli × mega

Significant figures

General rules for determining significant figures:

(1) The leftmost non-zero digit is **the most significant figure**.

(2) If there is no decimal point, the rightmost non-zero digit is **the least significant figure**.

(3) If there is a decimal point, the rightmost digit is **the least significant digit**, even if it is a zero.

(4) All digits between the most significant digit and the least significant digit are **significant figures**.

Significant figures

1.200 has __ significant figures.

1200 has __ significant figures.

1200. has __ significant figures.

1200.0 has __ sf.

1.2 has__ sf.

0.012 has __ sf.

Significant figures

1.200 has _4_ significant figures.

1200 has _2_ significant figures.

1200. has _4_ significant figures.

1200.0 has _5_ sf.

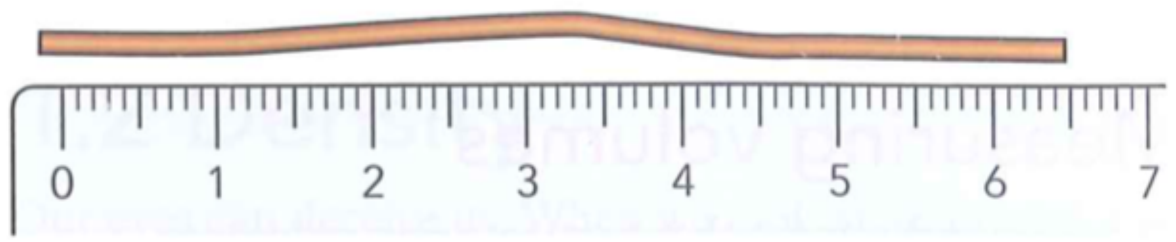
1.2 has_2_ sf.

0.012 has _2_ sf.

Measuring length

Try to measure the length of a **wire** yourself, answer following questions.

- What do you have to consider before measuring?
- How do you do the measurement?
- How do you read the result?
- How about measuring the thickness of a sheet of paper?
- How do you measure curved lines?

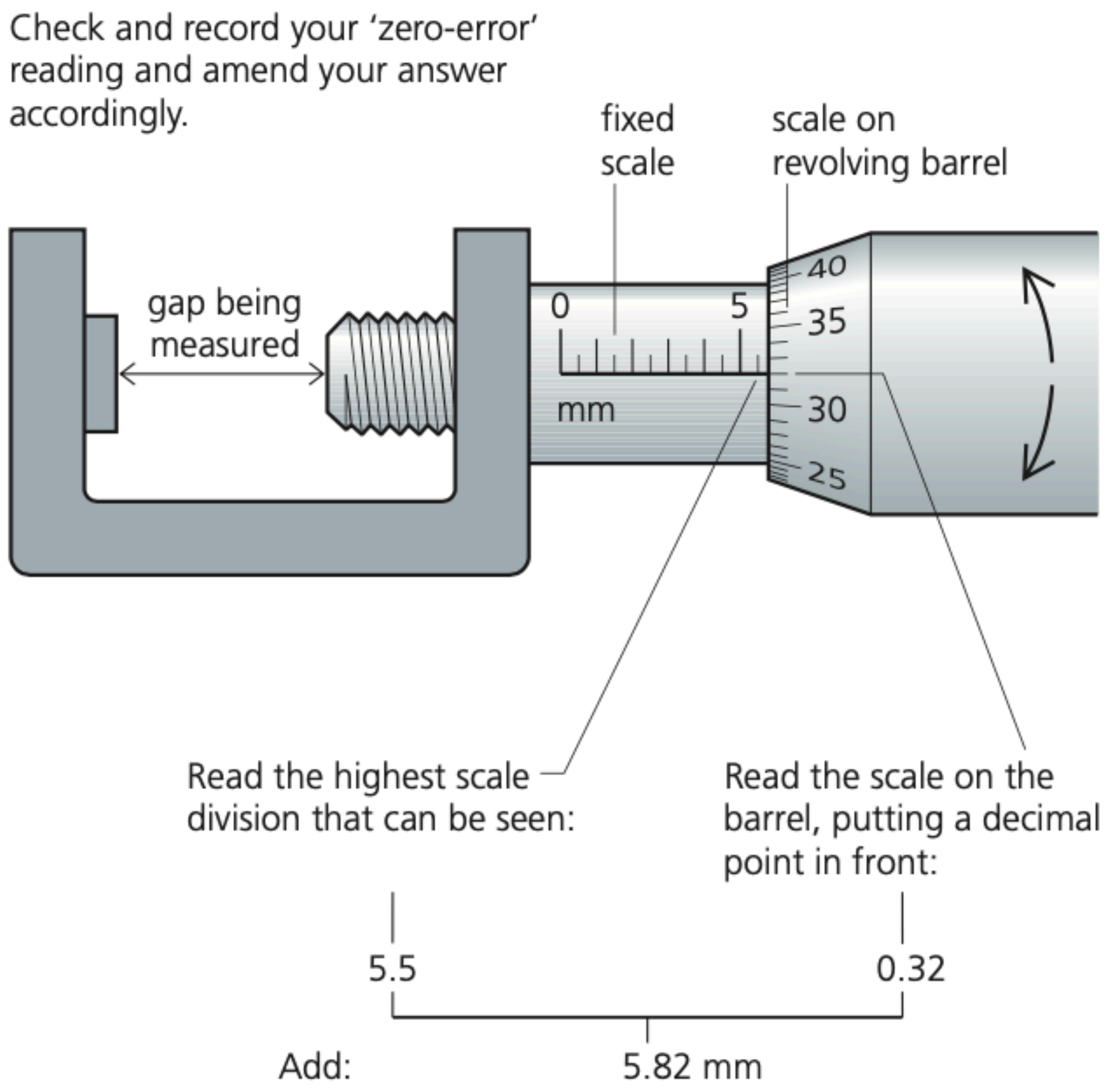


Measuring length

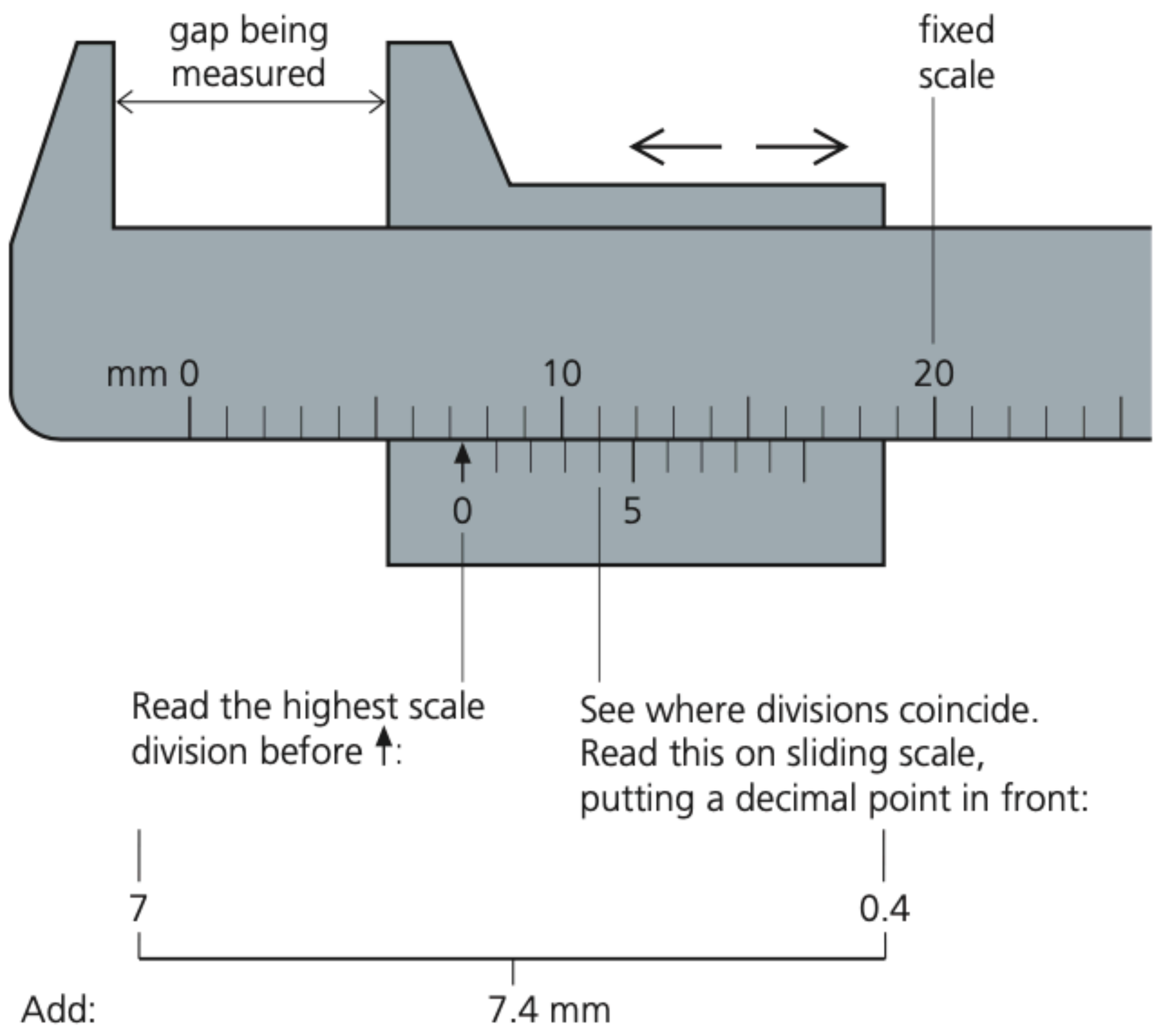
More measuring techniques

1. Measure a small length => **measure multiples, calculate the average**
2. Measure a curved line => use a thread, mark the thread, measure the thread
3. Check zero
4. Avoid parallax
5. Repeat the process and find the mean
6. Start at a recognizable point

More precise equipments



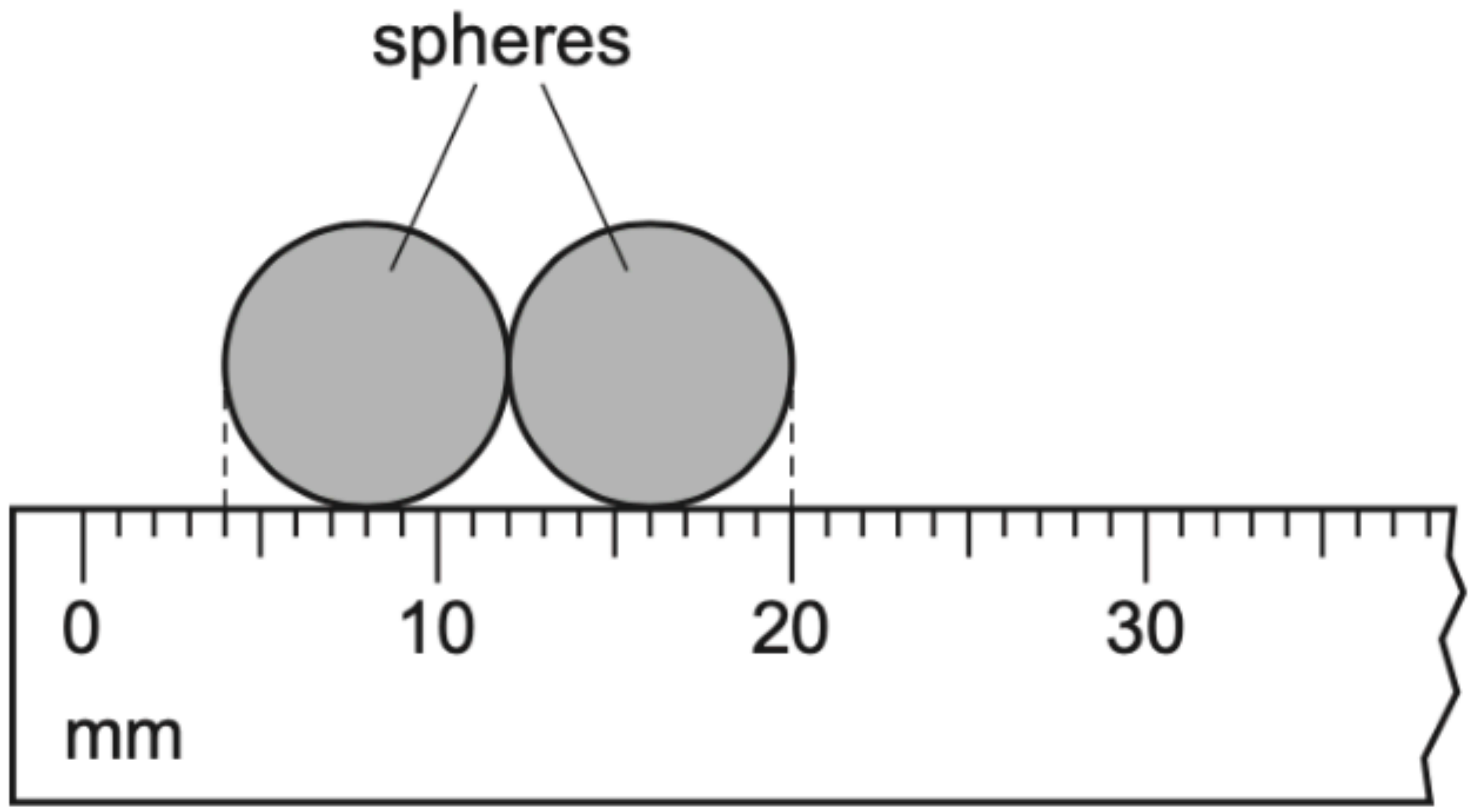
▲ Reading a micrometer



▲ Reading a vernier

Exam-style questions

The diagram shows two identical spheres placed beside a ruler.



What is the radius of one sphere?

A 4.0 mm **B** 5.0 mm **C** 8.0 mm **D** 10 mm

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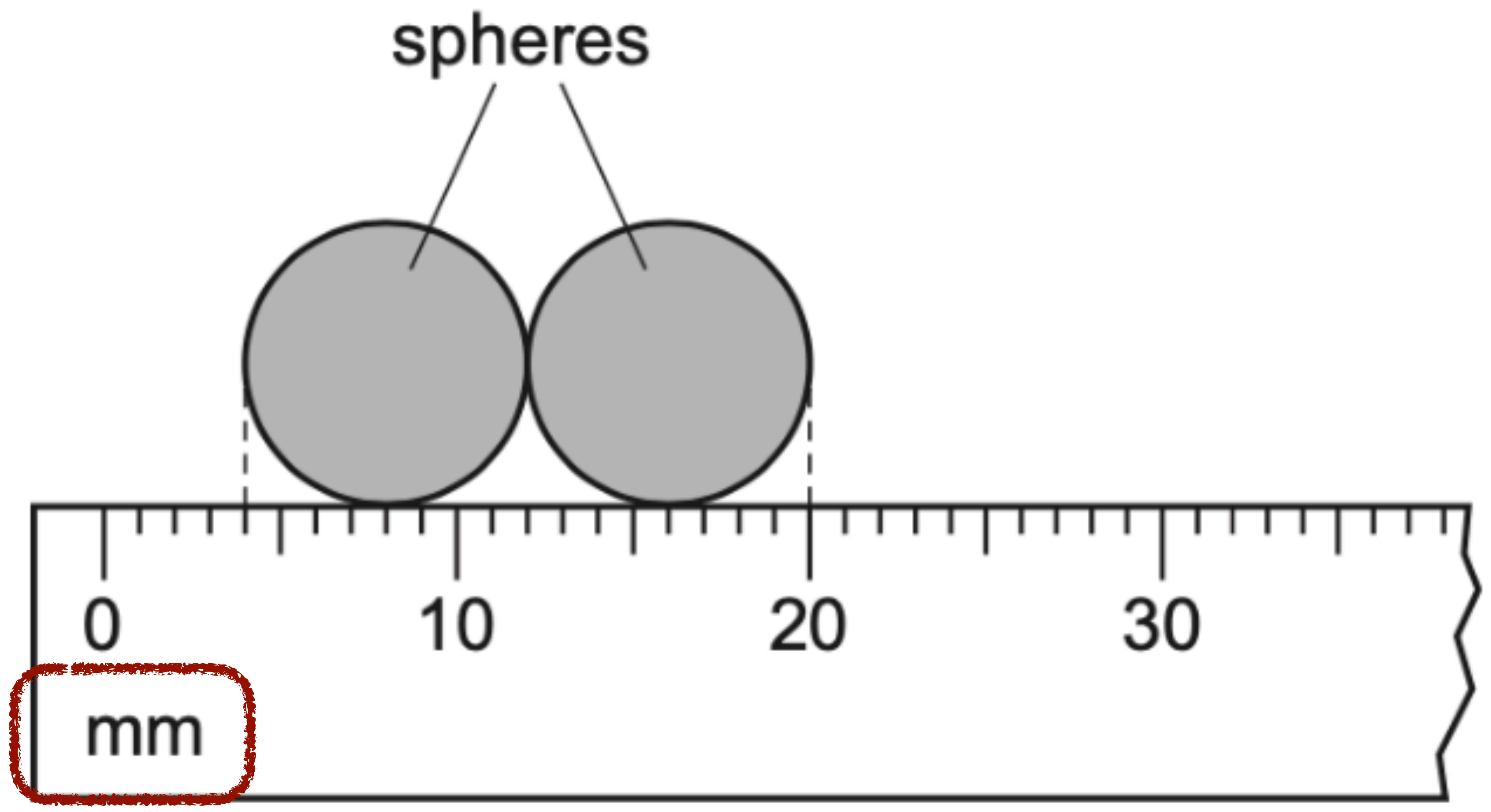

What is the radius of one sphere?

A 4.0 mm **B** 5.0 mm **C** 8.0 mm **D** 10 mm

Exam-style questions

(a) A coin collector has 19 identical coins, as shown in Fig. 1.1.

Fig. 1.1

Fig. 1.2 shows one of the coins in the coin collector's hand.

Fig. 1.2

The coin collector wants to check the thickness of one coin. She has a 30 cm ruler.

Describe how she can use the 30 cm ruler to determine the thickness of one coin accurately.

You may include a diagram if you wish.

....

....

....

.... [3]

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any **three** from: (put some coins) on top of each other OR in a stack idea measure the (total) thickness (of stack) 10 or more coins thickness (of one coin) = total thickness / 'length' ÷ number of coins	**B3**

.... [3]

Measuring area

Unit:

Square metre(m^2)

Exercise: 1.f

1 square decimetre(dm^2) $=$ m^2

1 square centimetre(cm^2) $=$ m^2

Measuring area

Unit: Square metre(m^2)

1 square decimetre(dm^2) $= 0.01m^2 = 10^{-2}m^2$

1 square centimetre(cm^2) $= 0.0001m^2 = 10^{-4}m^2$

Exercise: 1.g Measure the area of a A4 paper sheet.

Measuring area

Exercise: 1.g Measure the area of an A4 paper sheet.

$$29.7\,cm \times 21.0\,cm = 623.70cm^2$$

Round to 2 decimal places?

Keep 3 significant figures?

Measuring volumes

Unit

Exercise: 1.h

$1\ dm^3 = \qquad m^3$

$1\ cm^3 = \qquad m^3$

$1\ liter(l) = 1(\qquad)$

$1\ milliliter(ml) = 1(\qquad) = \qquad m^3$

Measuring volumes

Unit

Exercise: 1.h

$1\ dm^3 = 10^{-3}\, m^3$

$1\ cm^3 = 10^{-6}\, m^3$

$1\ liter(l) = 1(dm^3)$

$1\ milliliter(ml) = 1(cm^3) = 10^{-6}\, m^3$

Measuring volumes

1. Liquid:

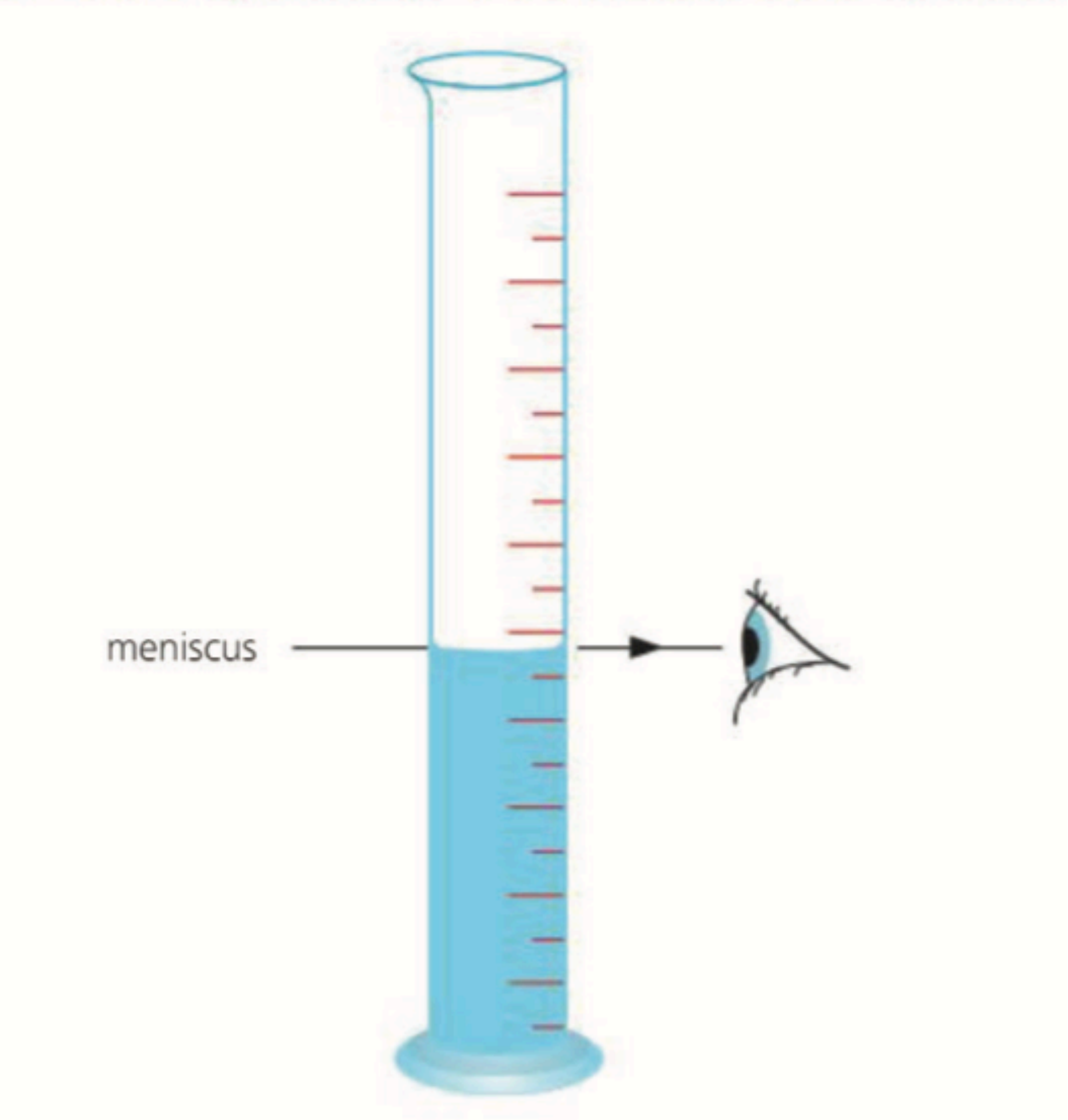
tool: measuring/graduated cylinder

meniscus: curved upper surface of a liquid

read the result: eyes should be level with the scale

choice of cylinder: the volume of liquid to be measured

$\approx$ half of cylinder's capacity



Exercise: 1.h

Volume to be measure is around 300ml, which of following cylinder’s capacity is most suitable?

A. 100 cm^3 B. 250 cm^3 C. 500 cm^3 D.1000 cm^3

Measuring volumes

2. Solid: regular shape:

Volume of a cuboid =

Volume of a cube =

Volume of a sphere =

Volume of a cylinder =

Measuring volumes

2. Solid: regular shape:

Volume of a cuboid = $w \times l \times h$

Volume of a cube = a^3

Volume of a sphere = $\dfrac{4}{3}\pi r^3$

Volume of a cylinder =$\pi r^2 h$

Measuring volumes

2. Solid: irregular shape:

technique: ***displacement*.**

Explain in your own words, how to use displacement to measure a rock. What is the key step?

Measuring volumes

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Explain in your own words, how to use displacement to measure a rock. What is the key step?

A. ~~Select a cylinder that is about 2-3 times larger than the object.~~

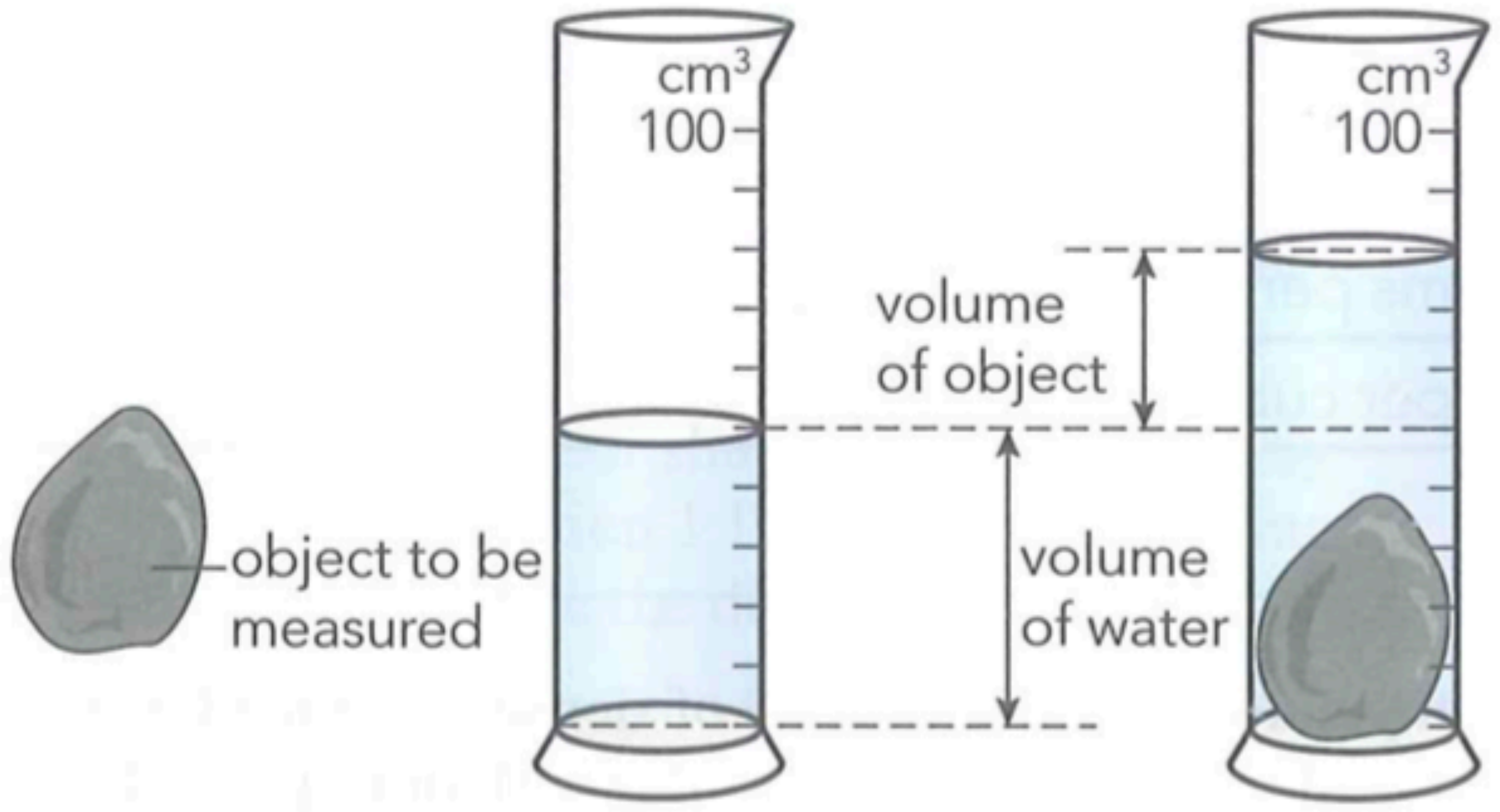
B. Partially fill it with water, enough to cover the object.

C. Read the volume of water.

D. **Immerse** the object in the water.

E. Read the new volume.

F. New volume - original volume = the volume of the object



Exam-style questions

(a) A student has an irregularly shaped piece of metal, a beaker of water and a measuring cylinder, as shown in Fig. 2.1.

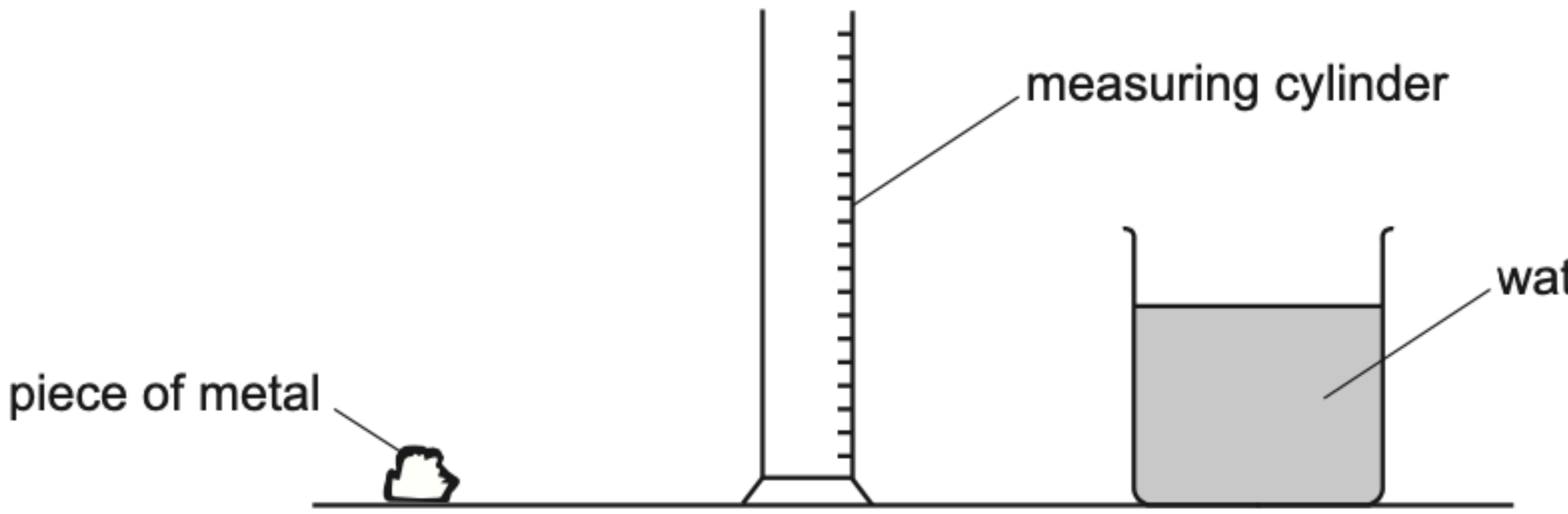


Fig. 2.1

Describe how the student can accurately determine the volume of the piece of metal using the equipment provided.

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.... [4]

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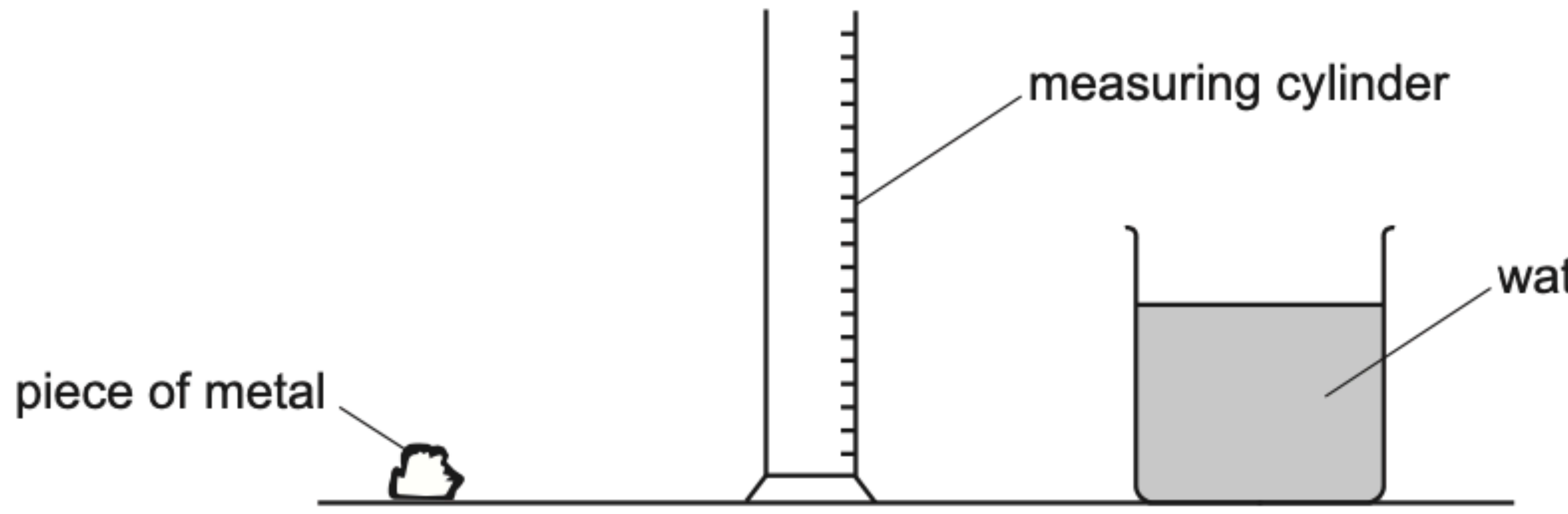


Fig. 2.1

Describe how the student can accurately determine the volume of the piece of metal using the equipment provided.

....

Any **four** from:
pour some water into measuring cylinder
record volume / reading of water (in measuring cylinder)
place metal in water (in cylinder and completely submerge)
record volume of water and metal (in cylinder)
subtract starting volume from final volume (to give volume of metal)

.... [4]

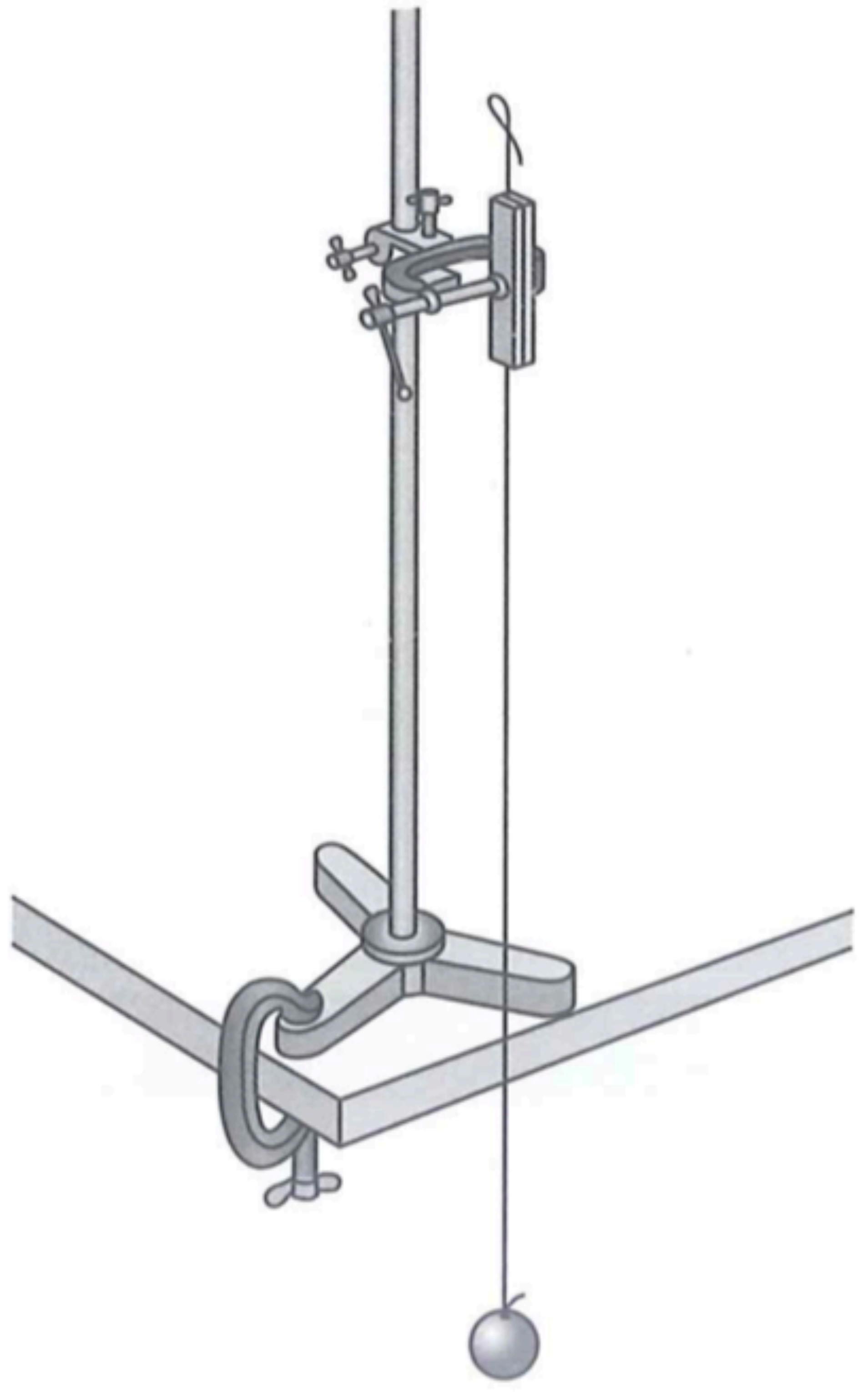
Measuring time

tool: *analogue* clock; *digital* clock/stopwatch

Measuring short intervals of time

e.g. measure the period of a pendulum.

Measuring a large number of oscillations and divide the number and calculate the average.



Mass

Def. of Mass: The quantity(amount) of matter in an object at rest to the observer.

Unit of mass: kilogram (kg) 1kg = ____ g

Tool to measure mass: balance

Mass is not weight.

Weight: the downward force of gravity that acts on an object because of its mass

Tip of iceberg

Why can people easily float on the Dead Sea?

Density

Def. of density : The ratio of mass to volume $density = \frac{mass}{volume}$, $\rho = \frac{m}{V}$

Unit of density: kg/m^3

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

Density of water: $\_\_\_\_ kg/m^3 = \_\_\_\_ g/cm^3$

Values of density

	Material	Density/kg/m³
Gases	air	1.29
	hydrogen	0.09
	helium	0.18
	carbon dioxide	1.98
Liquids	water	1000
	alcohol (ethanol)	790
	mercury	13 600
Solids	ice	920
	wood	400–1200
	polyethene	910–970
	glass	2500–4200
	steel	7500–8100
	lead	11 340
	silver	10 500
	gold	19 300

Table 1.3: Densities of some substances. For gases, these are given at a temperature of 0 °C and a pressure of 1.0×10^5 Pa.

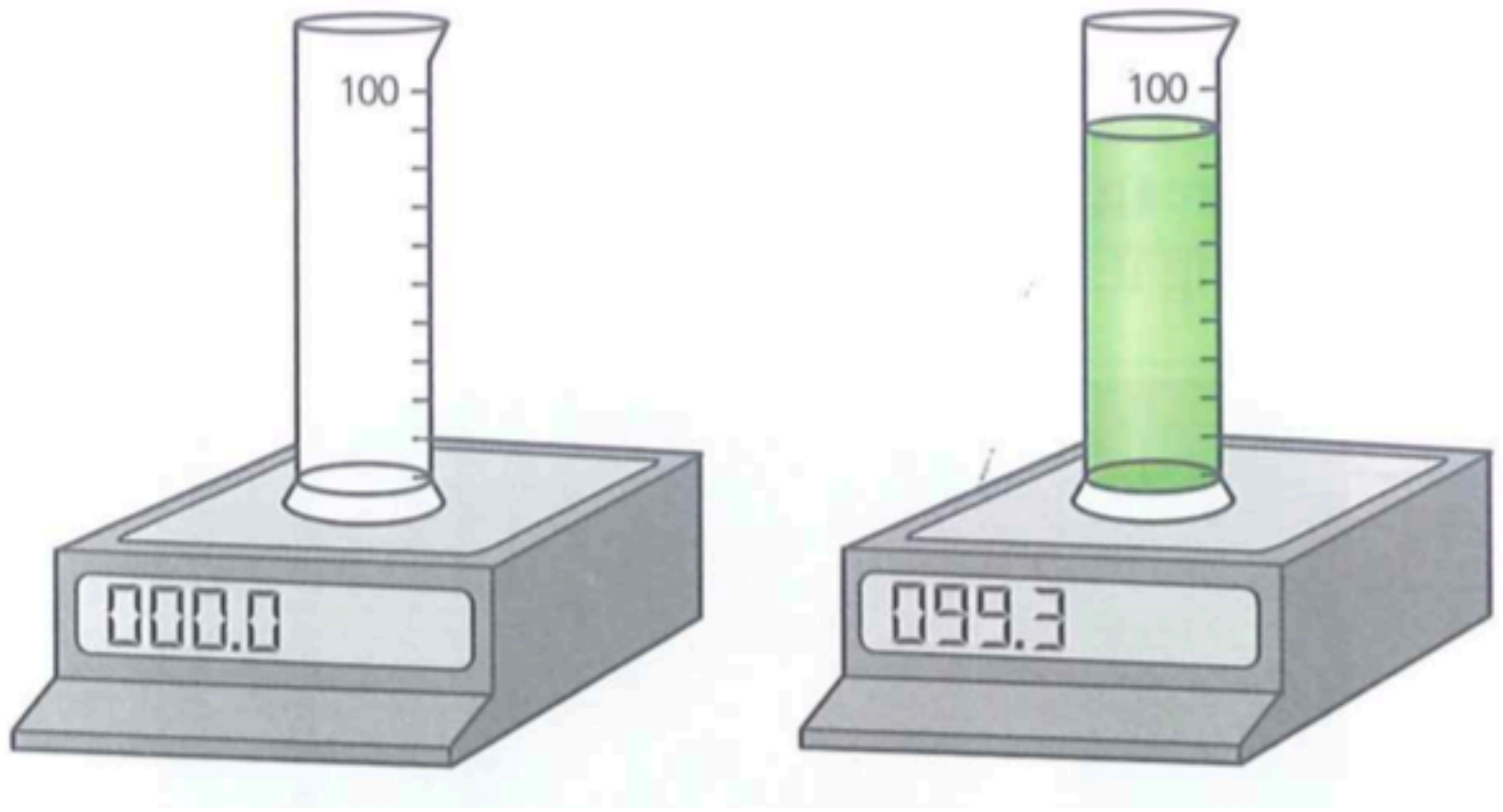
Calculating density

Density of earth:

The Earth has a mass of $6 \times 10^{24}\ kg$ and a radius of about $6400\ km$.

Finding the density of a liquid

How to use a balance and a measuring cylinder to measure the density of liquid?



Finding the density of a liquid

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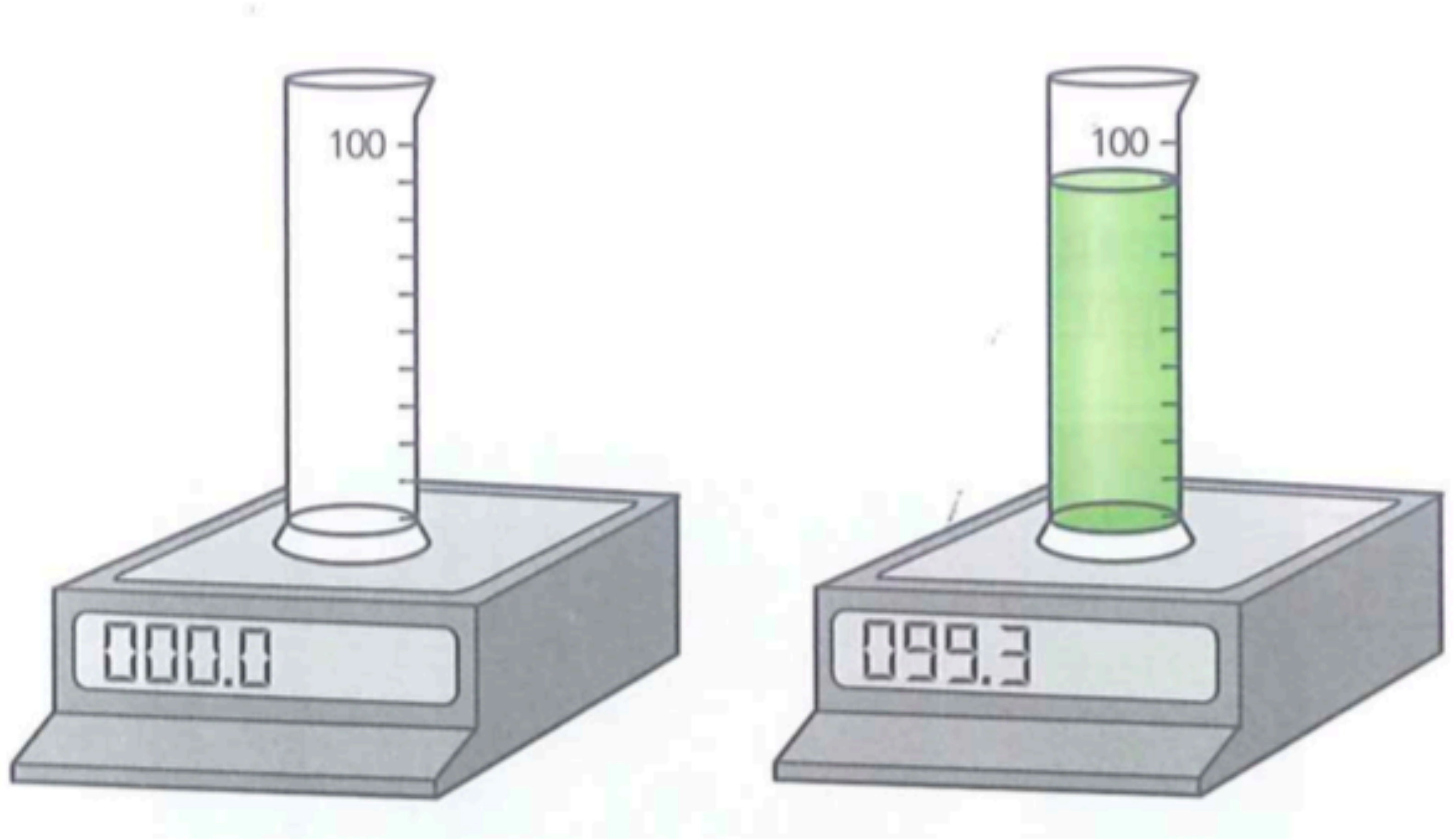
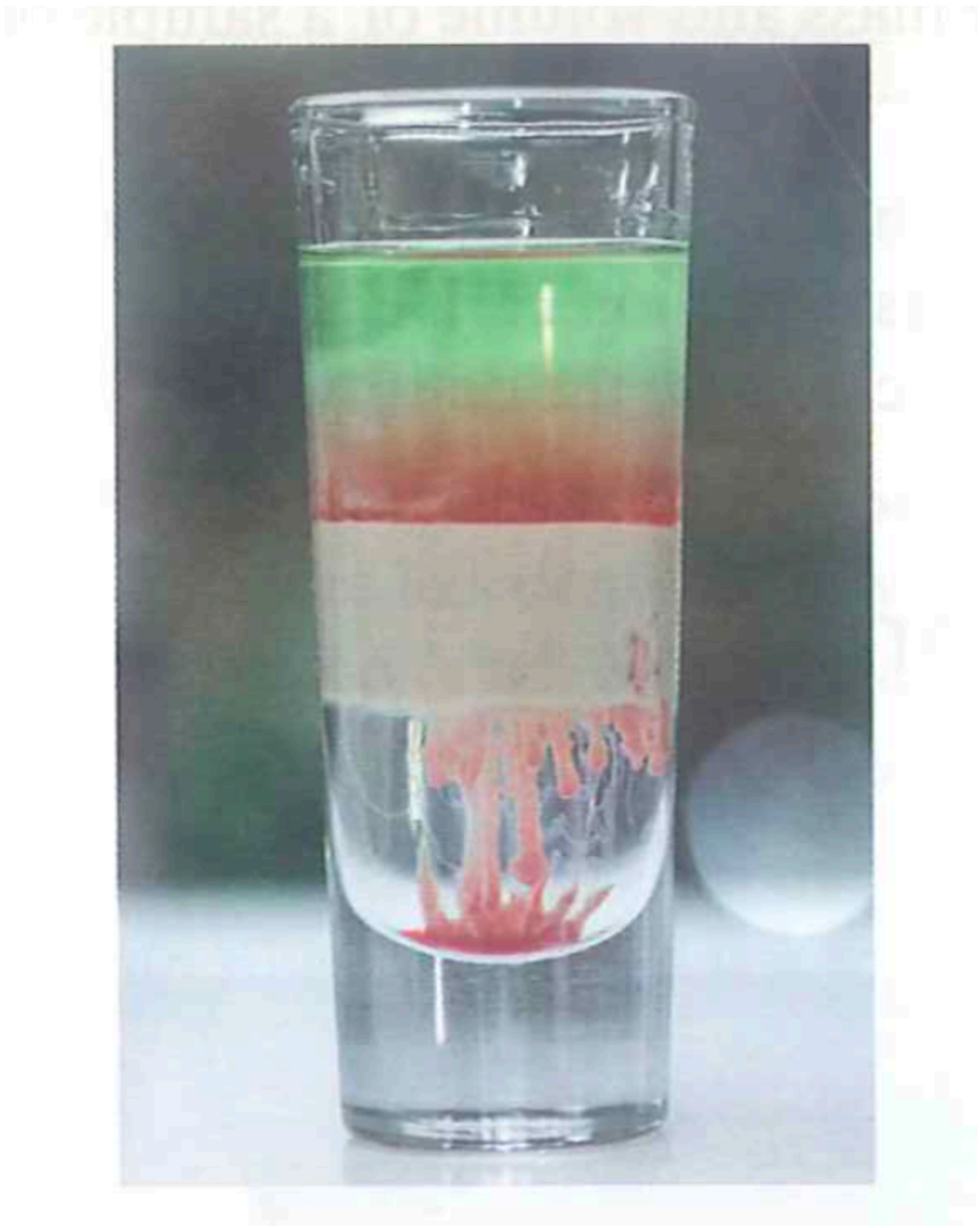


1. Place the measuring cylinder on a balance
2. Set the balance to **Zero**
3. Pour the liquid into the cylinder
4. Read the scale on the cylinder
5. Read the numbers on the balance

Liquids with different densities

Immiscible: form distinct layers with less dense liquids on the top



Water & oil?

Water & alcohol?

Liquids with different densities

Miscible: dissolve in one another

Summary

1. Physical quantities: scalar vs vector, SI unit, standard notation, prefix
2. Measuring length, area, volumes
3. Measuring density