Units and Measurements

الوحدات القياس

1.1 Physical Quantities

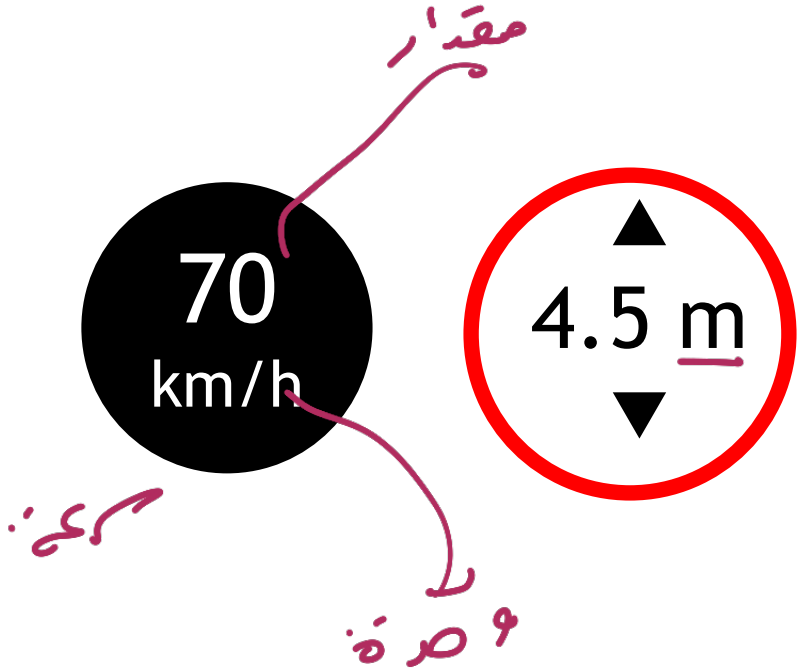
Quantitative versus qualitative

- Most observation in physics are quantitative
- Descriptive observations (or qualitative) are usually imprecise

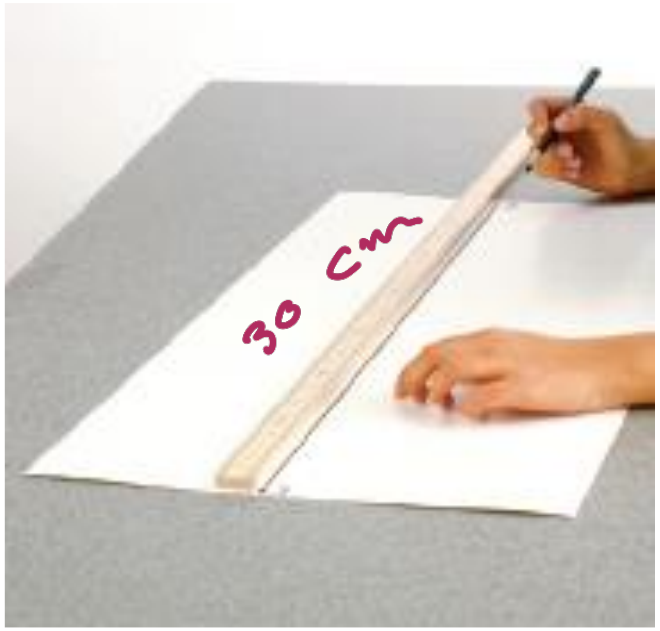
Qualitative Observations	Quantitative Observations
How do you measure artistic beauty?	What can be measured with the instruments ?

Physical Quantities

- A physical quantity is one that can be measured and consists of a magnitude and unit.



Measuring length



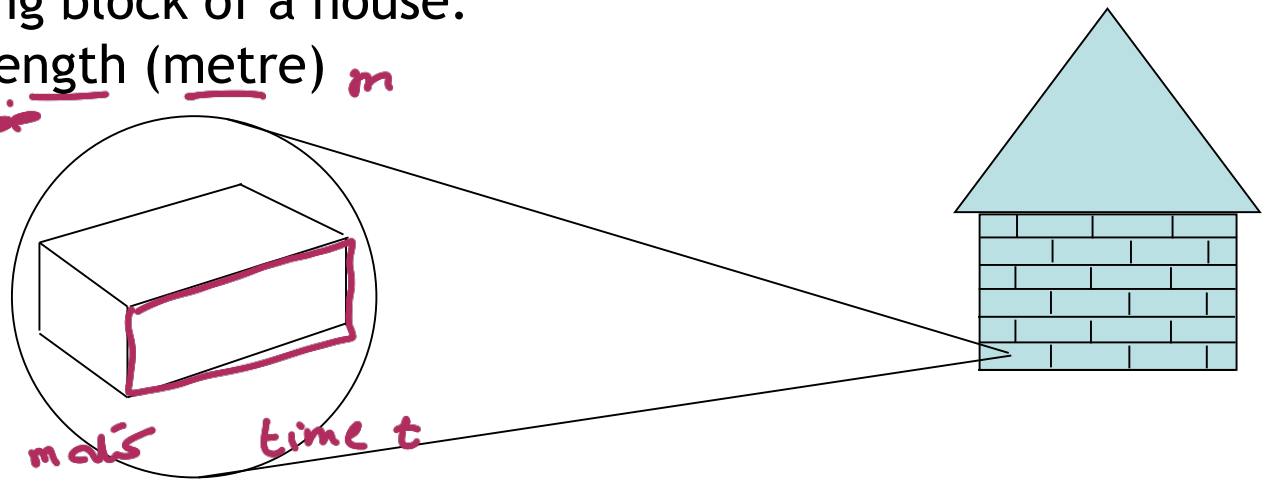
1.1 Physical Quantities

Are classified into two types:

- Base quantities
- Derived quantities

Base quantity
is like the brick – the basic building block of a house.
e.g. Length (metre)

Derived quantity is like the house that was build up from a collection of bricks (basic quantity) e.g. speed



Length m
mass kg
time t s
speed m/s

Different systems of measurements

In earlier time scientists of different countries were using different systems of units for measurement. Three such systems, the CGS, the FPS (or British) system and the MKS system were in use extensively till recently.

The base units for length, mass and time in these systems were as follows :

- In **CGS system** they were centimeter, gram and second respectively.
- In **FPS system** they were foot, pound and second respectively.
- In **MKS system** they were meter, kilogram and second respectively.

SI Units نظام قياس الوحدات العالمي

The system of units which is at present internationally accepted for measurement is the نظام دولي مقبول للقياس

Système Internationale d' Unites

النظام العالمي للوحدات

(French for International System of Units), **S.I.**

رموز ووحدات واختصارات

abbreviated as SI. The SI, with standard scheme of symbols, units and abbreviations, was developed and recommended by General Conference on Weights and Measures in 1971 for international usage in scientific, technical, industrial and commercial work

المؤتمر الدولي للقياس والأوزان

SI Units

- **SI Units** – International System of Units

Base Quantities	Name of Unit	Symbol of Unit
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

الوحدات المشتقة

SI Units

- Example of derived quantity:

معادلة مساحة طول × عرض مشتقة

Defining equation: area = length × width = m × m = m^2

In terms of units: Units of area = m × m = m^2

حجم

Defining equation: volume = length × width × height (m^3)

In terms of units: Units of volume = m × m × m = m^3

كثافة الكتلة الحجم

Defining equation: density = mass ÷ volume = $\frac{kg}{m^3}$

In terms of units: Units of density = kg / m^3 = kg m^{-3}

$\frac{kg}{m^3} = kg/m^3 = kg\,m^{-3}$

S.I. Units

- Work out the derived quantities for:

Defining equation: $\text{speed} = \dfrac{\text{distance}}{\text{time}}$

In terms of units: Units of speed = m/s

Defining equation: $\text{acceleration} = \dfrac{\text{velocity}}{\text{time}}$

In terms of units: Units of acceleration = m/s^2

Defining equation: force = mass × acceleration

In terms of units: Units of force = kg x m/s^2

$= kg \times \frac{m}{s^2} = kg \cdot m/s^2$

(N) نيوتن $= kg \cdot m\,s^{-2}$

SI Units

- Work out the derived quantities for:

Defining equation: $\text{Pressure} = \dfrac{\text{Force}}{\text{Area}}$

In terms of units: Units of pressure = $\dfrac{kg \cdot m}{s^2 \, m^2} = \dfrac{kg}{s^2 m}$

Defining equation: $\text{Work} = \text{Force} \times \text{Displacement}$

In terms of units: Units of work = $N \cdot m$

Defining equation: $\text{Power} = \dfrac{\text{Work done}}{\text{Time}}$

In terms of units: Units of power = $\dfrac{N \cdot m}{s} = N \cdot m/s$

SI Units

Derived Quantity	Relation with Base and Derived Quantities	Unit	Special Name
area	length × width	$m \times m = m^2$	m^2
volume	length × width × height	$m \times m \times m = m^3$	m^3
density	mass ÷ volume	$\frac{kg}{m^3} = kg/m^3$	—
speed	distance ÷ time	$\frac{m}{s} = m/s$	—
acceleration	change in velocity ÷ time	$\frac{m/s}{s} = m/s^2$	—
force	mass × acceleration	$kg \cdot m/s^2$	newton (N)
pressure	force ÷ area	$\frac{N}{m^2} = N/m^2$	pascal (Pa)
work	force × distance	$N \cdot m = Nm$	joule (J)
power	work ÷ time	$\frac{Nm}{s} = Nm/s$	watt (W)

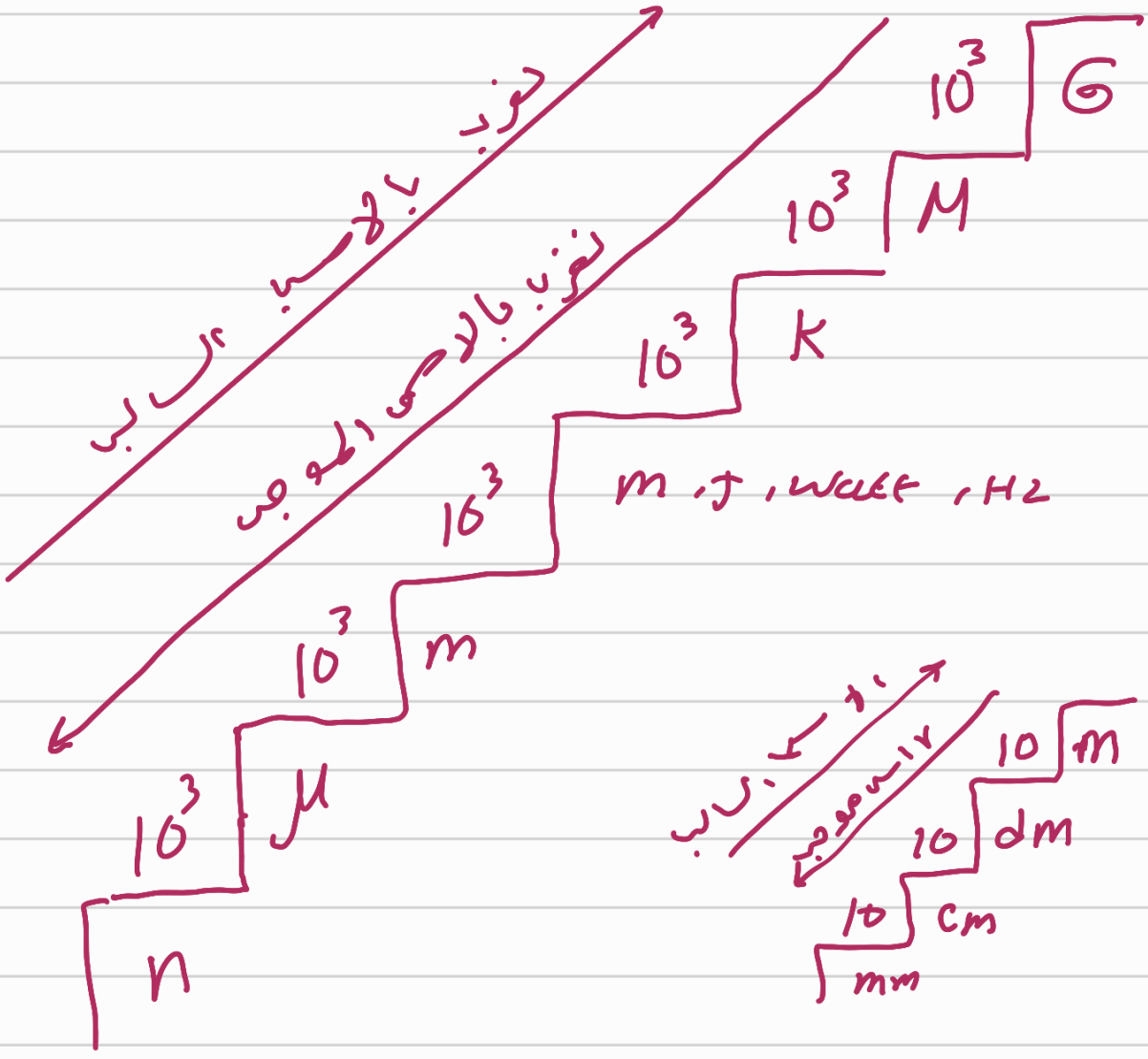
Prefixes

بادئات

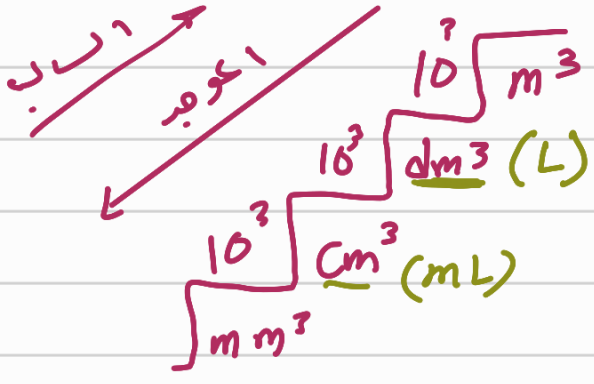
بادئات تستخدم لكتابة الوحدات الكبيرة والصغيرة

- Prefixes simplify the writing of very large or very small quantities

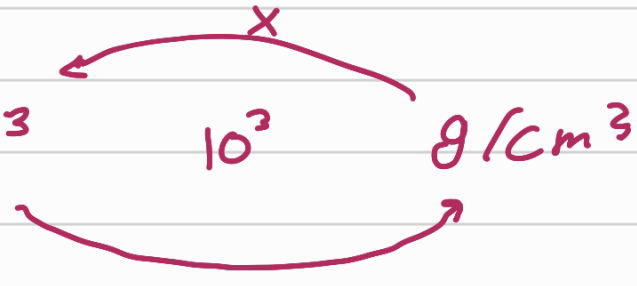
بادئة Prefix	Abbreviation	Power
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
kilo	K	10^{3}
mega	M	10^{6}
giga	G	10^{9}



حجم



كثافة



$0.00023 = 2.3 \times 10^{-4}$

$2300006 = 2.3 \times 10^{6}$

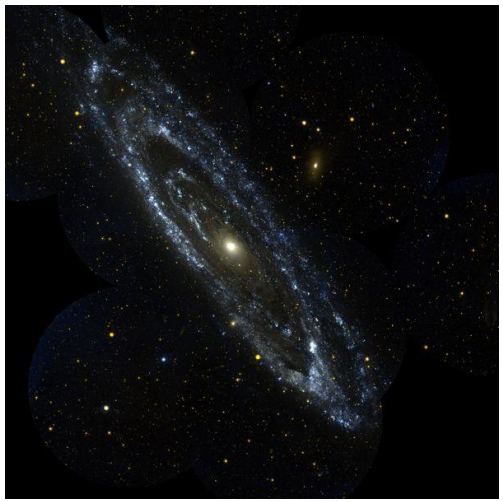
Prefixes

23584.21

الصيغة العلمية يجب ان تكون بين ١ و ١٥

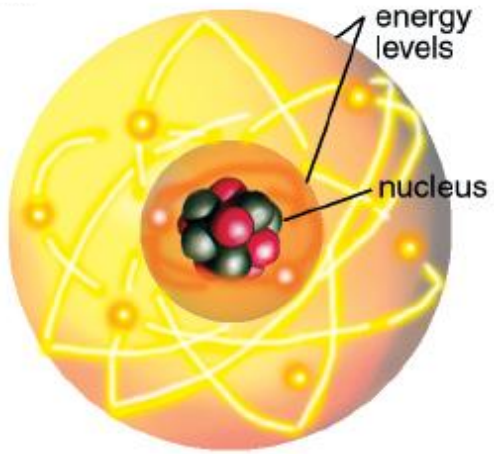
2.4×10^{4}

- Alternative writing method
- Using standard form الصيغة الموزبة
- $N \times 10^{n}$ where $1 \leq N < 10$ and n is an integer



This galaxy is about 2.5×10^{6} light years from the Earth.

2500000



قطر الذرة

The diameter of this atom is about 1×10^{-10} m.

0.0000000001

1×10^{-10} m

QUESTIONS

1 Name the base quantities and identify their SI units. What are the convenient ways of writing very large and very small quantities? using prefixes

2 Rewrite the following quantities using suitable prefixes.

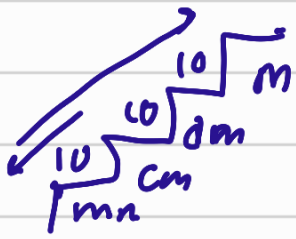
(a) 5 000 000 J 5MJ
(b) 48 000 g 48 kg
(c) 0.0009 s $\times 10^3$ 0.9 s
(d) 485 000 N 485 k
(e) 0.000 007 m 7 μm

3 Rewrite the following measurements in the units suggested.

(a) 760 mm in m
(b) 4.5 μs in s
(c) 3.2×10^3 m in km
(d) 10^{-1} cm in mm
(e) 7.2 km in mm
(f) 2.5 ms in μs

4 How many bytes of memory space are there in an 80 GB hard disk? (B in GB stands for byte)

③ ✓ 760 mm → m

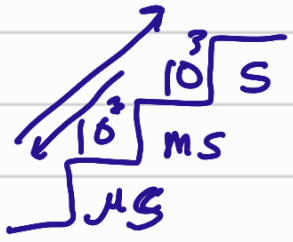


$760 \times 10^{-3} = 0.76$ m

✓ 10^{-1} cm mm

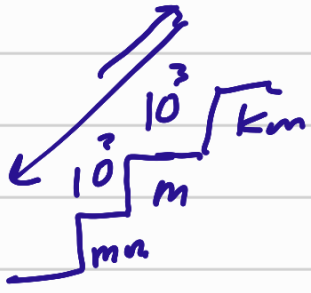
$10^{-1} \times 10 = 1$

✓ 4.5 μs → s



4.5×10^{-6} s

✓ 7.2 km → mm



7.2×10^{6} mm

✓ 3.2×10^{3} m → km

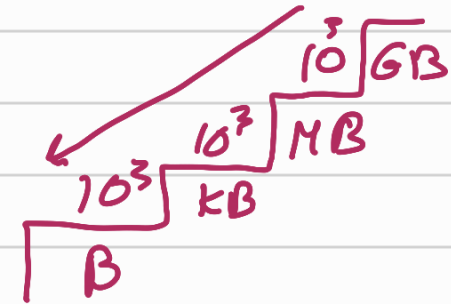
$3.2 \times 10^{3} \times 10^{-3} = 3.2$ km

✓ 2.5 ms → μs

2.5×10^{3} μs

8GB → B

8×10^{9} B



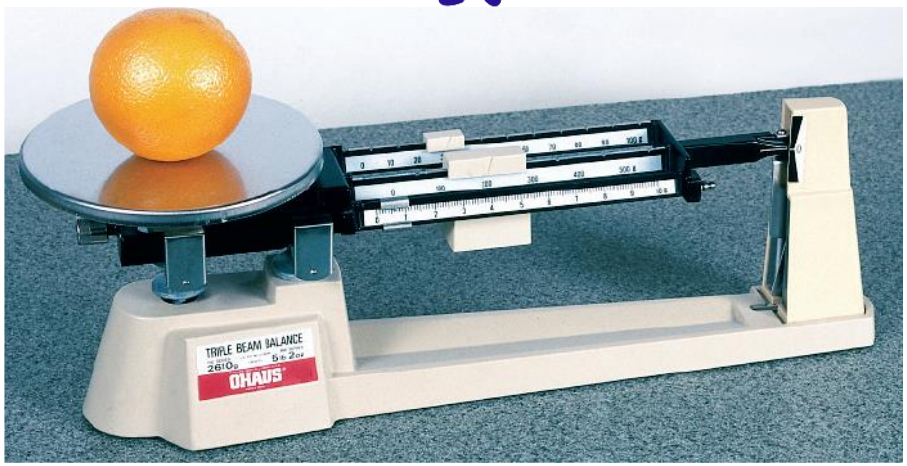
Scalars and Vectors

كميات قياسية هتقط مقدار بدون اتجاه

- **Scalar quantities** are quantities that only have magnitude. Example distance (meter)

Measuring Mass

كتلة



درجة حرارة

Measuring Temperature

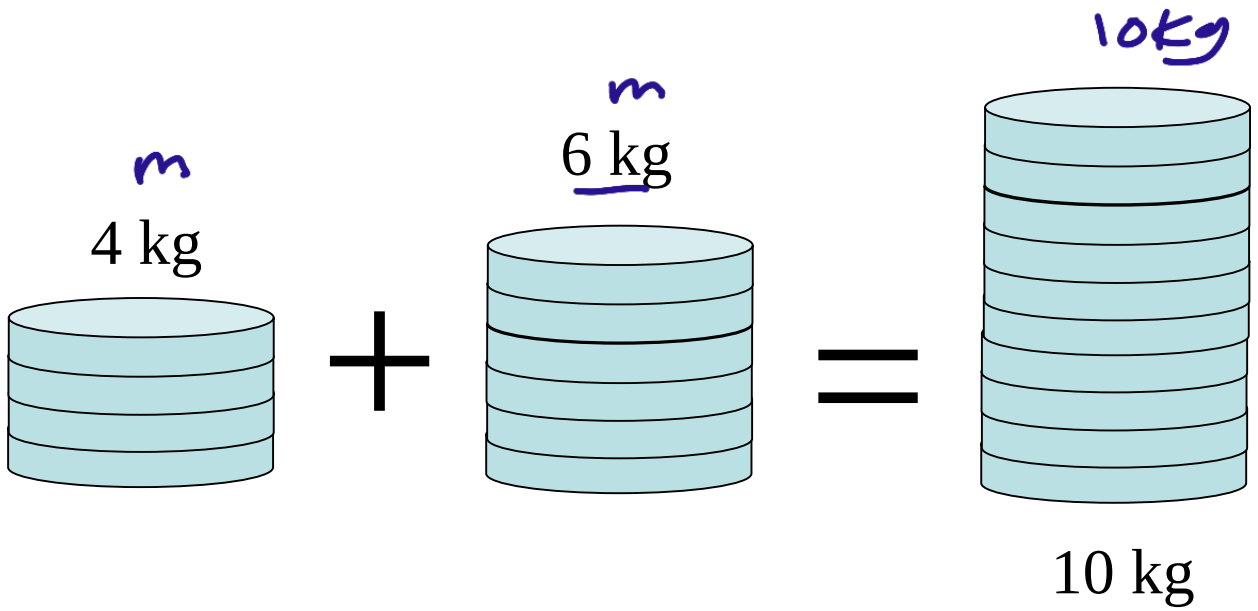
20+10=30
30-5=25

Scalars

الكميات القياسيه تجمع جمعاً جبرياً عادي

- **Scalar quantities** are added or subtracted by using simple arithmetic.

Example: 4 kg plus 6 kg gives the answer 10 kg

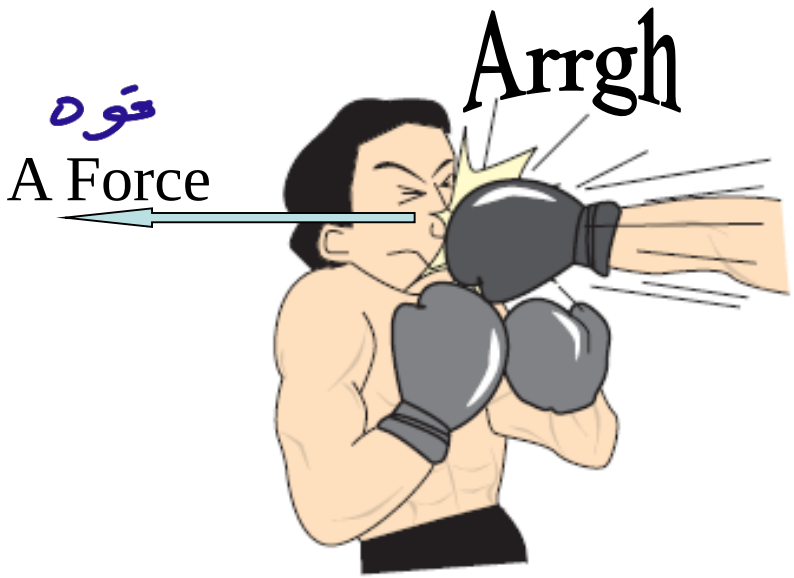


Scalars and Vectors

کمیات سمتی

- **Vector quantities** are quantities that have both magnitude and direction

که هم مقدار و هم جهت



نیرو

Magnitude = 100 N

Direction = Left

Scalars and Vectors

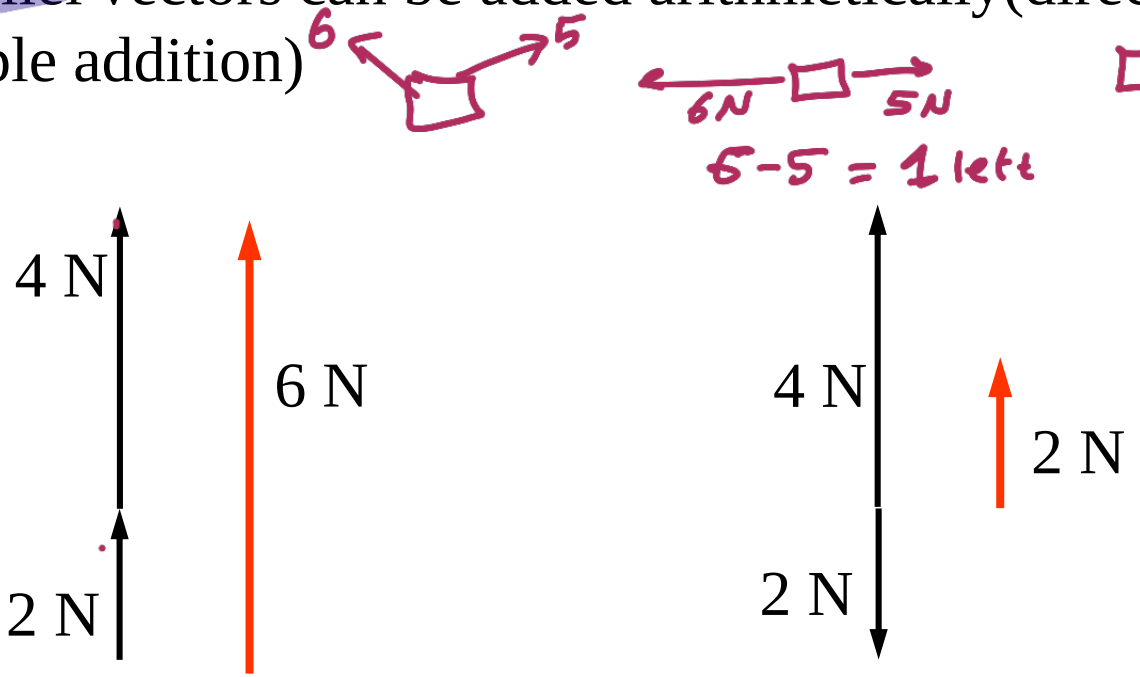
- Examples of scalars and vectors

Scalars	Vectors
distance	displacement
speed	velocity
mass	weight
time	acceleration
pressure	force
energy	momentum
volume	
density	

Scalars and Vectors

Adding Vectors using Graphical Method

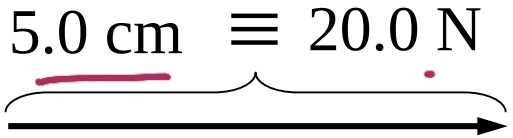
- Parallel vectors can be added arithmetically(direct simple addition)



Scalars and Vectors

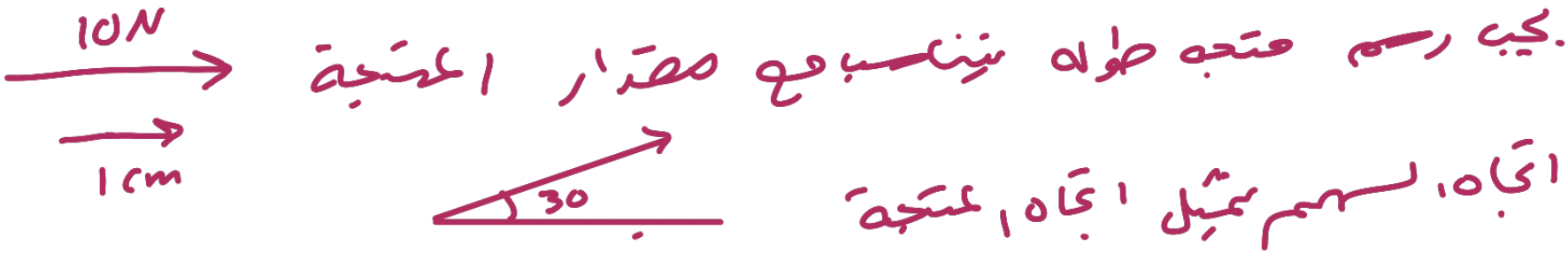
Adding Vectors using Graphical Method

- Non-parallel vectors are added by graphical means using the parallelogram law
  - Vectors can be represented graphically by arrows

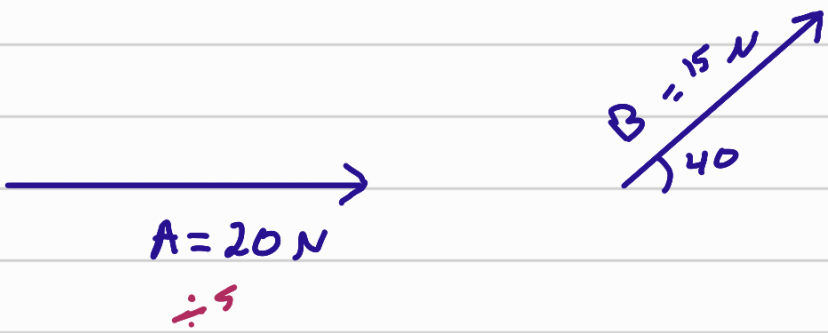


Direction = right

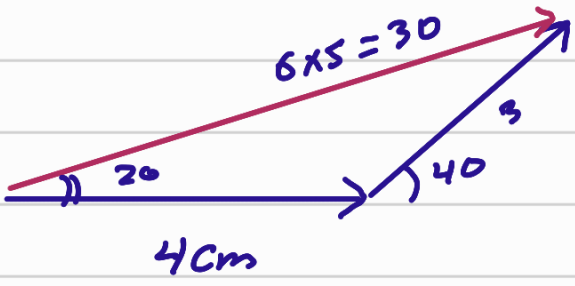
  - The length of the arrow represents the magnitude of the vector
  - The direction of the arrow represents the direction of the vector
  - The magnitude and direction of the resultant vector can be found using an accurate scale drawing



الطريقة ①



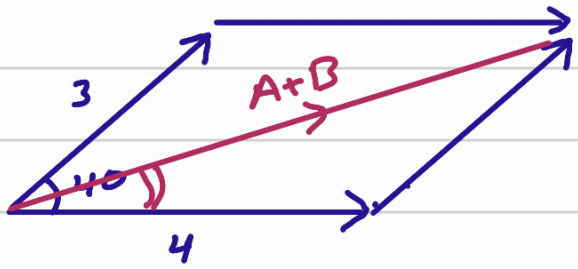
مقدار $A+B = 30$
الاتجاه 20°

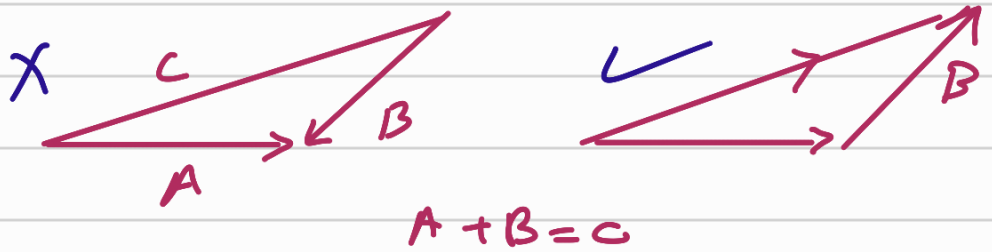


يرسم المتجه الاول
ثم من رأس المتجه
الاول يرسم المتجه
الثاني بنفس الطول
وبنفس الاتجاه

طريقة ② متوازي الاضلاع

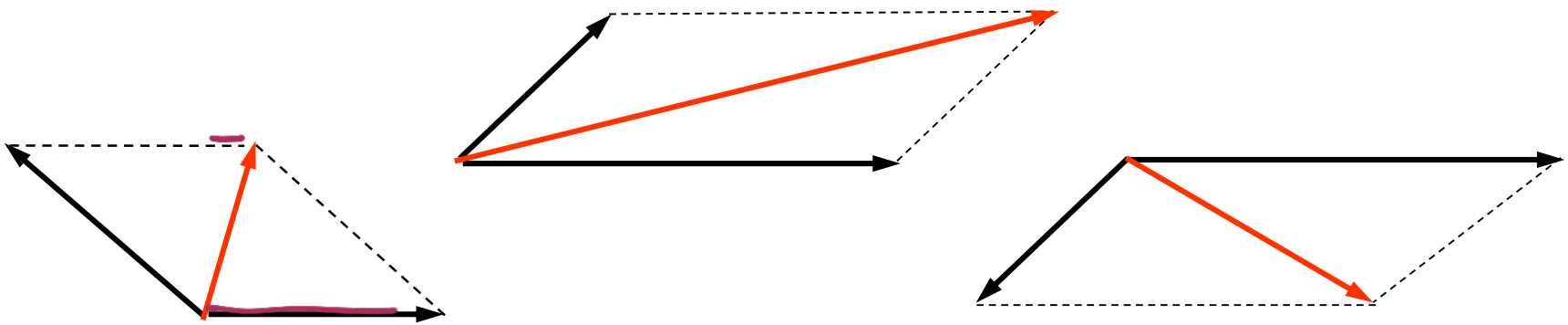
طريقة متوازي الاضلاع





Scalars and Vectors

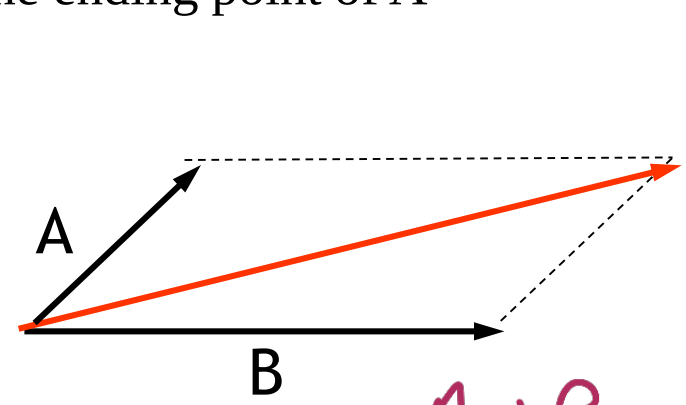
The **parallelogram law of vector addition** states that if two vectors acting at a point are represented by the sides of a parallelogram drawn from that point, their resultant is represented by the diagonal which passes through that point of the parallelogram



طريقة اخرى لجمع المتجهات

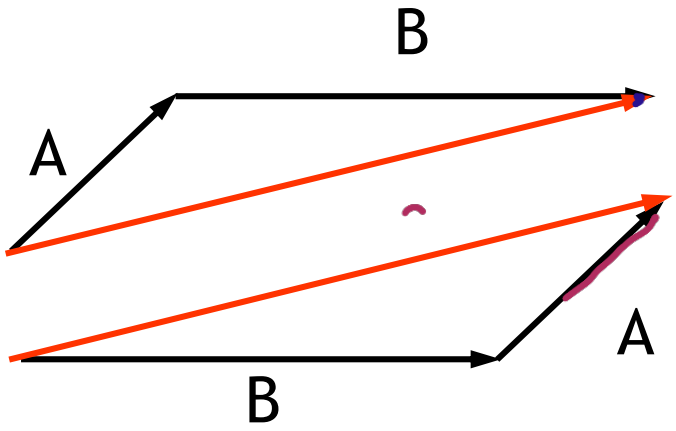
Another method of Adding Vectors

- To add vectors *A* and *B* ارسم بداية B على نهاية A
  - place the starting point of *B* at the ending point of *A*
  - The vector sum or resultant *R* is the vector joining the starting point of vector *A* to the ending point of *B* المحصلة هي من نقطة بداية A الى نهاية B
  - Conversely, *R* can also be obtained by placing the starting point of A at the ending point of B ويجوز ان نقوم بنفس العملية بدأ من B
  - Now the resultant is represented by the vector joining the starting point of B to the ending point of A



A + B

B + A



KEY CONCEPTS

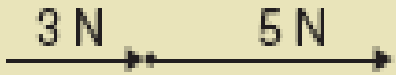
1. Scalar quantities are quantities that only have magnitudes
2. Vector quantities are quantities that have both magnitude and direction
3. Parallel vectors can be added arithmetically
4. Non-parallel vectors are added by graphical means using the parallelogram law

QUESTIONS

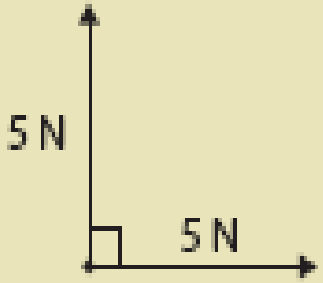
1 Determine the resultant force in each of the following situations. F_R

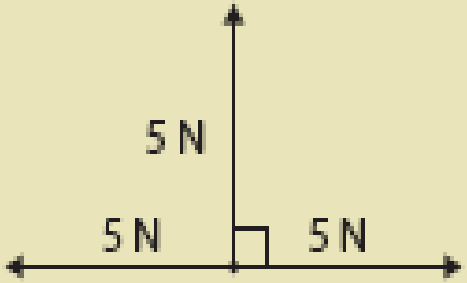
(a) 

$F_R = 5 - 3 = 2N$ east

(b) 

$F_R = 3 + 5 = 8N$

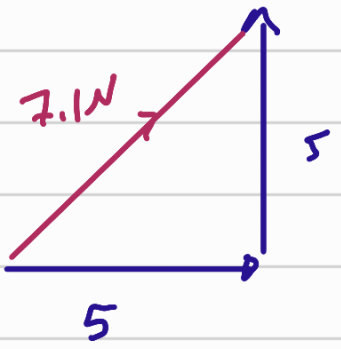
(c) 

(d) 

2 Two forces of magnitudes 5 N and 8 N act on a body. What are the maximum and minimum resultant forces that can act on the body?

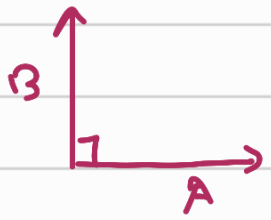
3 Two forces ***P*** and ***Q*** act on a body. The maximum and minimum forces that act on the body are 13 N and 7 N respectively. What are the magnitude of the forces ***P*** and ***Q***?

a)



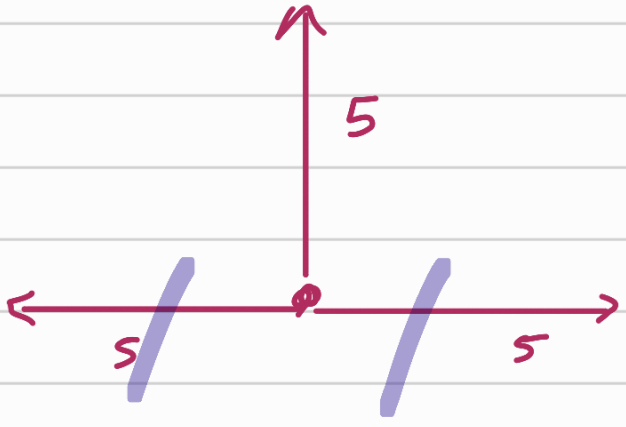
7.1N east North

نحوه ی بدست آوردن زاویه بین دو جهت 90°



$$F_R = \sqrt{A^2+B^2}$$
$$= \sqrt{5^2+5^2}$$
$$= 7.1\ N$$

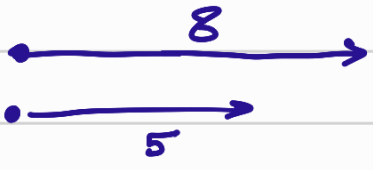
d)



$5-5=0$

$F_R = 5$ north

2)



Min = $8-5=3\ N$ ⟵ ⟶ = ⟵

Max = $8+5=13\ N$ ⟶ = 13 N

3)

Max = 13

Min = 7

⟶ 13

⟶ ⟵ 7

F = 10 N F = 3 N

SELF-MANAGEMENT

Carry out the following activities to make sure you have really understood this chapter.

I. Misconception Analysis

Think carefully about the following statements: Are they true or false? Check the answers at the back of the book to see whether you have any misconceptions.

1. Physical quantities must have both magnitude and unit. True / False
2. Base quantities and base units are the same. True / False
3. Derived quantities are not physical quantities. True / False
4. SI units for length, mass and time are the metre, gram and second respectively. True / False
5. Prefixes are used to express big numbers only. True / False
6. Non-parallel vectors cannot be added arithmetically. True / False
7. Parallax error is due to the incorrect positioning of the eye when taking readings. True / False
8. Zero error can be eliminated by taking more readings. True / False
9. A reading should be recorded as 10.0 cm instead of 10 cm when the measuring instrument is a metre rule. True / False
10. The period of oscillation for a pendulum increases with length. True / False

II. Self-Check

Complete Self-Check 1 to check what you should know and understand in this chapter. Go to the Longman website to download the checklist.

III. Self-Reflection

Complete a Self-Reflection sheet for this chapter and reflect on what you have learnt. Go to the Longman website to download the sheet.

PRACTICE

I. Multiple Choice Questions

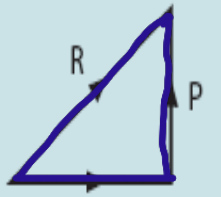
1. Which of the following quantities is not a base quantity?
   (A) length (C) temperature
   (B) weight (D) electric current

2. Which of the following is the longest length?
   (A) 3.54×10^{3} mm (C) 3.54×10^{4} m
   (B) 3.54×10^{3} cm (D) 3.54×10^{5} km

3. When two forces are combined, the magnitude of the resultant force depends on the angle between the two forces. Which of the following cannot be the magnitude of the resultant force when forces of magnitude 3 N and 7 N are combined?
   (A) 3 N (C) 7 N
   (B) 4 N (D) 9 N

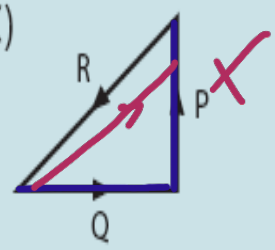
4. Which diagram correctly shows the addition of vectors P and Q?

(A)

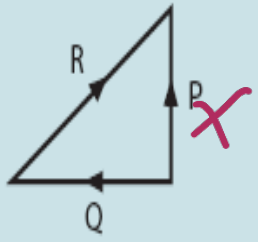


Q + P = R

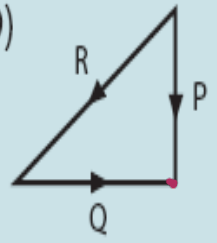
(C)



(B)



(D)



P − Q = R

5. A student doing an experiment needs to measure the internal diameter of a beaker as accurately as possible. Which instrument should he use?
   (A) measuring tape (C) vernier calipers
   (B) metre rule (D) micrometer

6. Figure 1.29 shows part of a vernier scale.

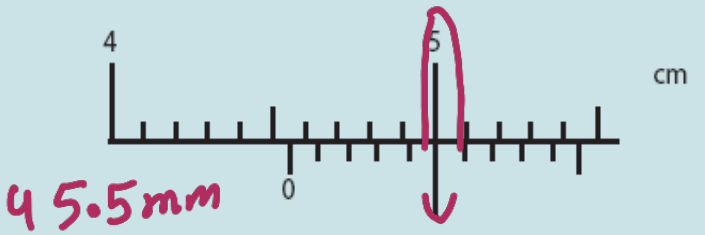


Figure 1.29

What is the reading on the vernier scale?

(A) 4.50 cm
(B) 4.55 cm
(C) 5.00 cm
(D) 5.45 cm

7. Figure 1.30 shows the vernier scale of a travelling microscope. What is the reading shown?

(A) 32.5 mm
(B) 35.5 mm
(C) 40.0 mm
(D) 44.5 mm

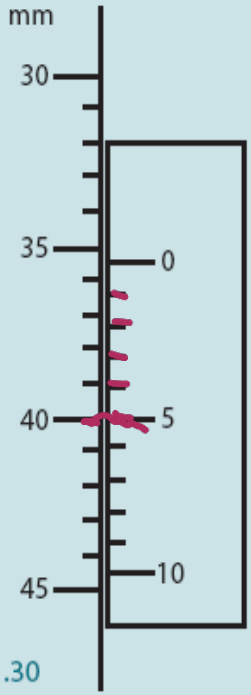


Figure 1.30

8. Figure 1.31 shows a micrometer scale. What is the reading shown?

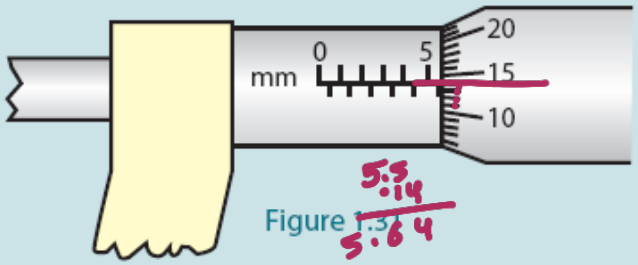


Figure 1.31

(A) 5.14 mm
(B) 5.16 mm
(C) 5.64 mm
(D) 5.66 mm

9. The time taken for the pendulum to swing from X to Y is 2.0 s.

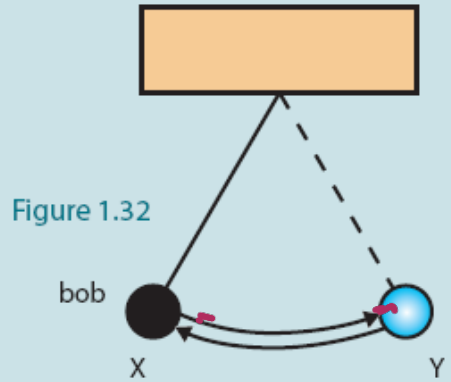
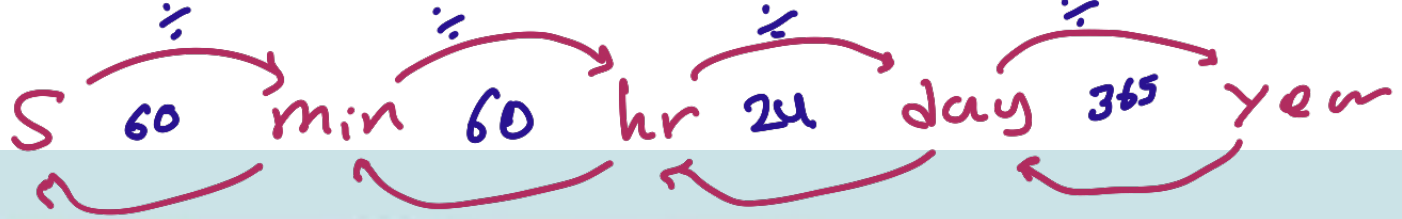


Figure 1.32

What is the time for one oscillation of the pendulum?

(A) 1.0 s
(B) 2.0 s
(C) 3.0 s
(D) 4.0 s



II. Structured Questions

$10^7 \div 60 \div 60 \div 24 \div 365 = 3 \times 10^9$ y

1. (a) The age of the Earth is 10^{17} s. What is the age of the Earth in years?

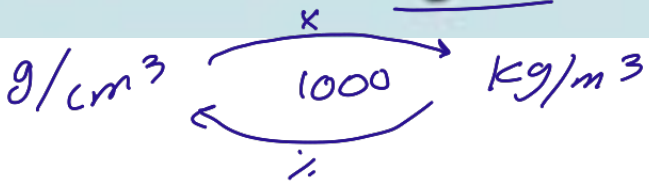
$\frac{0.08\text{ cm}}{1\text{ day}} = \frac{0.08 \times 10^{-2} \times 10^9\text{ nm}}{1 \times 24 \times 60 \times 60\text{ s}} = 9\text{ nm/s}$

(b) Suppose your hair grows at a rate of 0.08 cm per day. What is the rate at which it grows in nanometres per second?

$\frac{70\text{ km}}{1\text{ hr}} = \frac{70 \times 10^3}{1 \times 60 \times 60}\frac{\text{m}}{\text{s}} = 19.4\text{ m/s}$

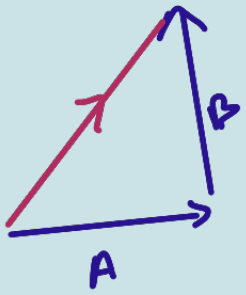
(c) The highway speed limit for cars is 70 km h^{-1}. What is the speed limit in m s^{-1}?

(d) The density of water is 1 g cm^{-3}. What is the density of water in kg m^{-3}? = 1000 kg/m³



2. (a) From the list below, which are vector quantities?
force, acceleration, distance, pressure, mass, speed

(b) When two forces of 10 N are added, the magnitude of the resultant force depends on the angle between the two forces.



(i) Describe how it is possible to produce a zero resultant force. 2 equal and opposite forces

(ii) Describe how it is possible to produce a resultant force of 20 N. ⟹ same direction

(iii) Draw a vector diagram to show how a resultant force of about 10 N may be obtained.

3. (a) A wooden block is placed beside a ruler as shown in Figure 1.34 below. What is the length of the wooden block?

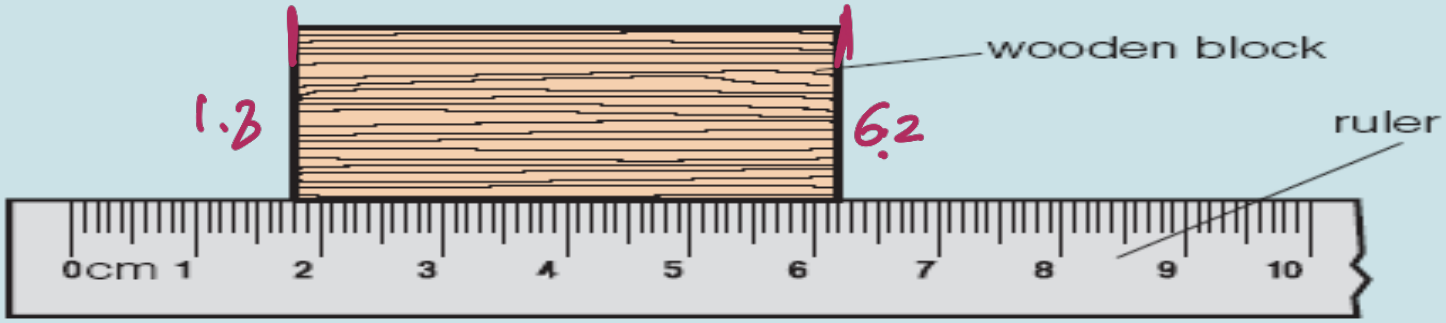


Figure 1.34

$l = 6.2 - 1.8 = 4.4$

(b) By using the data given in Figure 1.35, complete Table 1.8 with the appropriate measurement fo the physical quantities.

1.8 m	6000 km	4×10^8 m
1×10^{-4} m	10 000 m	

Figure 1.35

Physical quantity	Measurement
Height of Mount Everest	10 000
Radius of Earth	6000 km
Thickness of paper	1×10^{-4}
Distance from Earth to Moon	4×10^8
Height of a person	1.8

Table 1.8

4. (a) Table 1.9 shows measurements of the diameter of a rod using instruments P, Q and R.
Name the instruments in the space provided.

Instrument	Name of instrument	Diameter /cm
P	ruler	1.6
Q	vernier caliper	1.62
R	micrometer	1.623

Table 1.9

(b) To measure the diameter of a wire P, a student coiled the wire on a pencil and measured the length for 20 turns of the wire. Figure 1.36 shows the actual size of the objects.

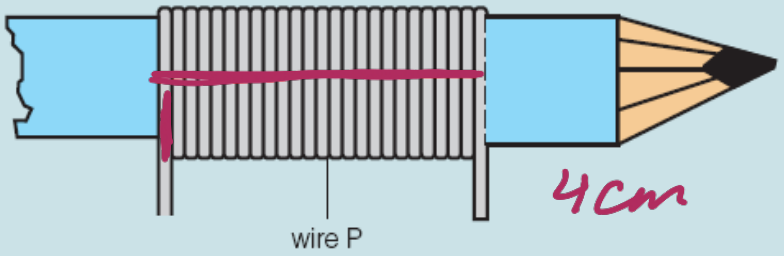


Figure 1.36

(i) Using a ruler, measure the length of 20 turns of wire P.
(ii) What is the diameter of wire P? $\frac{4}{20} = 0.2$cm
(iii) Name an instrument in the laboratory that is more suitable to measure the diameter of the wire P with.
micrometer

III. Critical Thinking Questions

1. Estimate the length of each of the following:
   (a) a desk,
   (b) a classroom,
   (c) a basketball court,
   (d) a football stadium.

2. Estimate the mass of the following objects:
   (a) an envelope,
   (b) an apple,
   (c) a basketball,
   (d) a desk,
   (e) a car.

3. (a) Estimate the number of times your heart beats in a day.
   (b) Estimate the number of times a human heart beats in an average lifetime.

4. An ancient unit of length called the cubit was defined as the length of six palms, where a palm was the width of four fingers of an open hand. In what ways was this a bad way to define a standard?