Name: **Index No:**

Date: **Class:**

Assignment 01: Physical quantities, units and measurements (IP)

1. (a) Make the following conversions. Show your working clearly. [9]

(i)	Express 2 x 10^{-2} MHz in kHz.	(ii)	Express 4.8 x 10^2 μm in cm.
	2 x 10^{-2} MHz = 2 x 10^4 Hz **= <u>20 kHz</u>** [1]		**4.8 x 10^2 μm = 4.8 x 10^{-4} m** **= <u>0.048 cm</u>** [1]
(iii)	Express 905 mm^2 in cm^2.	(iv)	Express 90 km h^{-1} in m s^{-1}.
	10 mm = 1.0 cm **Square both sides.** **100 mm^2 = 1.0 cm^2** $\therefore$ **905 mm^2 =** $\frac{1}{100} \times 905$ **= <u>9.05 cm^2</u>** [1]		**90 km h^{-1} =** $\frac{90\ km}{1\ h}$ $= \frac{90\ 000\ m}{3600\ s}$ [1] **= <u>25 m s^{-1}</u>** [1]
(v)	Express 1.36 x 10^4 kg m^{-3} in g cm^{-3} in **standard form**.	(vi)	Express 5.24 x 10^3 cm min^{-1} in m s^{-1} in **standard form**.
	1.36 x 10^4 kg m^{-3} = $\frac{1.36 \times 10^4\ kg}{1\ m^3}$ $= \frac{(1.36 \times 10^4 \times 1000) g}{100\ 00\ 00\ cm^3}$ [1] **= <u>1.36 x 10^1 g cm^{-3}</u>** [1]		**5.24 x 10^3 cm min^{-1} =** $\frac{5.24 \times 10^3\ cm}{1\ \text{min}}$ $= \frac{(5.24 \times 10^3 \times 10^{-2}) m}{60\ s}$ [1] **= <u>8.73 x 10^{-1} m s^{-1}</u>** [1]

Note:
For conversion, preserve the most s.f. as the quantity is usually used for subsequent calculations.

(b) Derive, in terms of base units, for:

(i) the watt W, the unit for power, where power is the rate of work done.

(ii) the coulomb C, the unit for charge, where electric current is the rate of flow of electric charge.

Show your working clearly. [2]

(i) power = work done / time taken **1 W = 1 kg m^2 s^{-2} / s** **= 1 <u>kg m^2 s^{-3}</u>** [1]	**(ii) current = charge / time taken** **1 A = 1 C / 1 s** $\therefore$ **1 C = <u>1 A s</u>** [1]

2. Fig. 2.1 shows the design of a window grille and Fig. 2.2 shows the magnified diagram of a metal bar segment attached to the window grille.

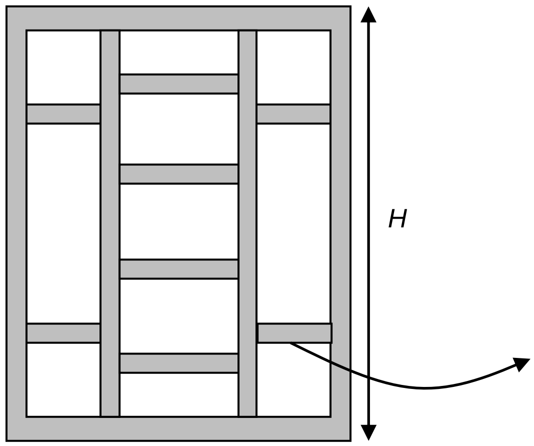


Fig. 2.1

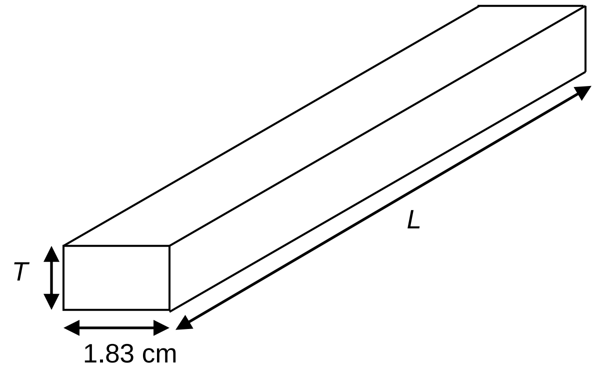


Fig. 2.2

(a) The length of the metal bar segment, *L*, is measured using a pair of digital calipers and recorded as 124.6 mm.

Using information from Fig. 2.1 and 2.2, state the instrument that is able to measure the following dimensions **most precisely**.

(i) Height of metal grille, *H* ....**metre rule/measuring tape**................. [1]

(ii) Thickness of metal bar segment, *T* ....**digital micrometer**....................................... [1]

[Note: Spelling of instruments]

(b) Given that T = 1.21 cm, determine the volume of a metal bar segment, in cm^3. [2]

Volume of metal bar segment = 1.21 cm x 1.83 cm x 12.46 cm [1]
= 27.59
= 27.6 cm^3 (correct to 3 s.f.) [1]

(c) Convert your answer in (c) to SI unit and leave your answer in standard form. [2]

27.6 cm^3 = 27.6 / 1000 000 **[1 m^3 = 1000 000 cm^3]**
= 2.76 X 10^{-5} m^3 [1: conversion]
[1: standard form] [Note: preserve s.f. for conversion]

(d) There is a discrepancy between the actual volume and the theoretical volume of the metal bar segment. According to the specifications, the theoretical volume of the bar segment is 28.5 cm^3 with an error tolerance of 5%.

Determine if the actual volume of the metal bar segment in (c) is acceptable within its tolerance. [2]

Minimum volume within tolerance = 0.95 x 28.5 = 27 cm^3
Maximum volume within tolerance = 1.05 x 28.5 = 29.9 cm^3 [1: appropriate calculations made]

Since the actual volume of 27.6 cm^3 falls in the range of 27 cm^3 to 29.9 cm^3, it is acceptable within its tolerance. [1: explanation]

3. Fig. 3.1 shows a square metal bar.

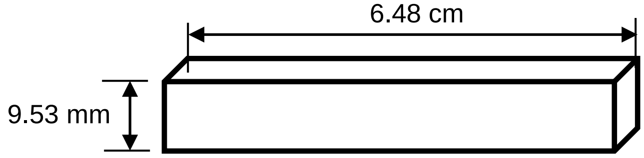


Fig. 3.1

(a) Suggest the laboratory instruments a student should use to measure the dimensions of the square bar to the required precision as stated in Fig. 3.1. [2]

Instrument to measure thickness of bar: **Digital micrometer (9.53 mm)**

Instrument to measure length of bar: **Digital calipers (6.48 cm)**

(b) The student took a few readings to determine the thickness of the square bar at different positions and obtained the average value of the dimension. Why is this step necessary? [2]

There will be greater accuracy [1] **as thickness of bar may not be uniform across its length** [1]. [Note: wrong to write 'to reduce random error' as the non-uniformity of the thickness of the bar is a variation of the object and not due to the random nature of measurement.]

(c) The mass of the bar is measured to be 5.021×10^{-2} kg. Determine the density of the bar, in g cm^{-3}, to the correct number of significant figures. Hence, state the material which the bar is possibly made of, with reference to the given list of metals below. [3]

material	density / g cm^{-3}
aluminum	2.70
copper	8.93
iron	7.87
zinc	7.13
brass	8.60

Volume of bar = 0.953 cm x 0.953 cm x 6.48 cm
= 5.8852 cm^3 [leave to more s.f. for subsequent calculations]

Density = mass/ volume = 5.021×10^{-2} kg / 5.8852 cm^3 [1]
= 50.21 g / 5.8852 cm^3
= 8.53 g cm^{-3} (to 3 s.f.) [1]

The bar is possibly made of **brass.** [1]

4. The following formula is related to thermal properties. By using the values shown in the table, work out the answer to the appropriate unit and presentation.

physical quantity	value of quantity
power, P	36 J s^{-1}
time taken, t	1.86×10^3 s
mass, m	0.20 kg
change in temperature, $\Delta\theta$	81 K

Use the formula $Pt = mc(\Delta\theta)$ to find the specific heat capacity, c, of the liquid. [3]

Some students expressed unit of c in base units which is $m^2\ s^{-2}\ K^{-1}$ which is also correct, but not necessary as it is not specified in the question.

$Pt = mc\Delta\theta$

$(36\ J\ s^{-1})(1.86 \times 10^3\ s) = (0.20\ kg)(c)(81\ K)$ [1]

$c = 4133$

$c = 4.1 \times 10^3$ J/(kg K) (2 s.f.) [1: correct s.f.][1: correct unit. Accept **J kg^{-1} K^{-1}**.]

5. Fig. 5.1 shows an experimental set up used by a student to determine the period of the pendulum. The student observes the swinging pendulum from the position shown in Fig. 5.1. Using a stopwatch, the student measures the time for 40 swings. Each swing is taken to be the planar motion of the bob from A to B **or** B to A. He repeats the process three times and records the reading in the table shown in Fig. 5.2. After some calculations, he concludes that the period of the pendulum is 1.02 s. The length of the pendulum bob is 1.000 m.

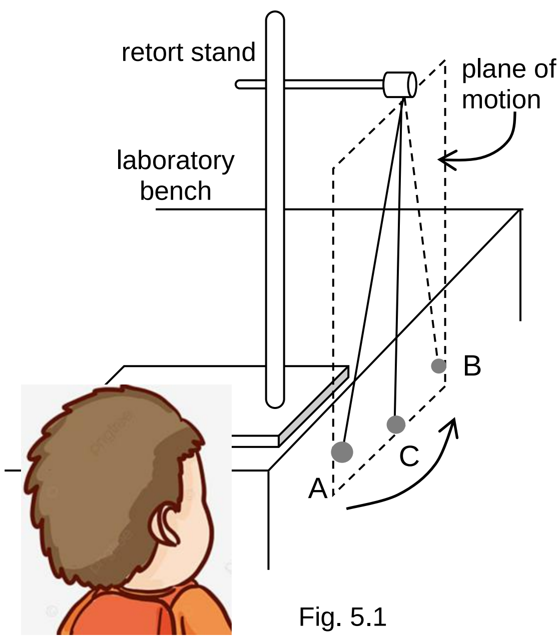


Fig. 5.1

Reading	Time for 40 swings / s	Period / s
1st	40.6	1.02
2nd	41.3	1.03
3rd	40.2	1.01
Average	40.7	1.02

Fig. 5.2

Source: https://pngtree.com/freepng/painted-back-home-boy-character-back-view-design_4376506.html

(a) A teacher approaches the student and tells him that he is observing the pendulum from the wrong position. Suggest what the student can do to correct this mistake. [1]

Position himself so that his line of sight is perpendicular to plane of motion of pendulum. [1]

[X: Position the eye at the same level as the pendulum bob / parallax error.]

(b) The student also makes a mistake when he determined the period of the pendulum during the experiment.

(i) State the correct period T of the pendulum. [1]

T = 40.7/20
= 2.035s
= <u>2.04 s</u> [1] **(correct to 3 s.f.)** [Note: s.f. of T follow s.f. of time taken for swings]

(ii) Explain the mistake the student made. [1]

He wrongly <u>defined one oscillation as one swing</u> from A to B or from B to A. [1]
<u>One oscillation</u> is <u>motion</u> of pendulum <u>from A to B and B to A</u>.
[Note: Students often mix up period and oscillation in their explanation
e.g. [wrong] He mistook one swing as one <u>period</u> of oscillation.]

(c) The student found that, given the length of the pendulum, L, the period, T of the pendulum could be used to determine the acceleration due to gravity, g. This relationship is given by

$$T = 2\pi\sqrt{\frac{L}{g}}.$$

Using the answer in (b)(i), calculate the acceleration due to gravity, g, in m s^{-2}. [2]

$$g = 4\pi^2 L/T^2$$
$$= 4\pi^2 (1.000\text{ m}) / (2.035\text{ s})^2$$ [1][Note: Substitute L = 1.000 m, not 1 m]
$$= 9.53\text{ m s}^{-2}$$ **(correct to 3 s.f.)** [1: correct s.f.]

[Students who used T = 2.04 s will get g = 9.49 m s^{-2}, which has early round off error.]

6. (a) Circle the correct estimate for the following quantities. [3]

(i) the density of a human body

1×10^1 kg m^{-3} 1×10^2 kg m^{-3} 1×10^3 kg m^{-3} 1×10^4 kg m^{-3}

Close to 1 x 10^3 kg m^{-3} or 1 g cm^{-3}. Actual density = 985 kg m^{-3}.
Human is made of 75% water.

Article by Scientific American: Sink or Swim: Muscle versus Fat
Source: https://www.scientificamerican.com/article/muscle-versus-fat/#:~:text=If%20an%20object%20has%20a,dense%20than%20water%2C%20it%20floats.&text=So%2C%20as%20it%20turns%20out,balance%20of%20fat%20and%20muscle.

(ii) the average speed of a marathon winner

5×10^{-1} m s^{-1} 5×10^0 m s^{-1} 5×10^1 m s^{-1} 5×10^2 m s^{-1}

Around 5 m s^{-1} or 20 km h^{-1}. A typical runner takes 2.5 hours to complete 42 km.

(i) the mass of an adult domestic cat

3×10^{-2} kg 3×10^{-1} kg 3×10^0 kg 3×10^1 kg

From 2.2 kg to 11 kg. Average mass = 4.45 kg.

(b) Explain why these suggested estimates are incorrect. [3]

(i) The power of a hot plate on a cooker is 2 W.

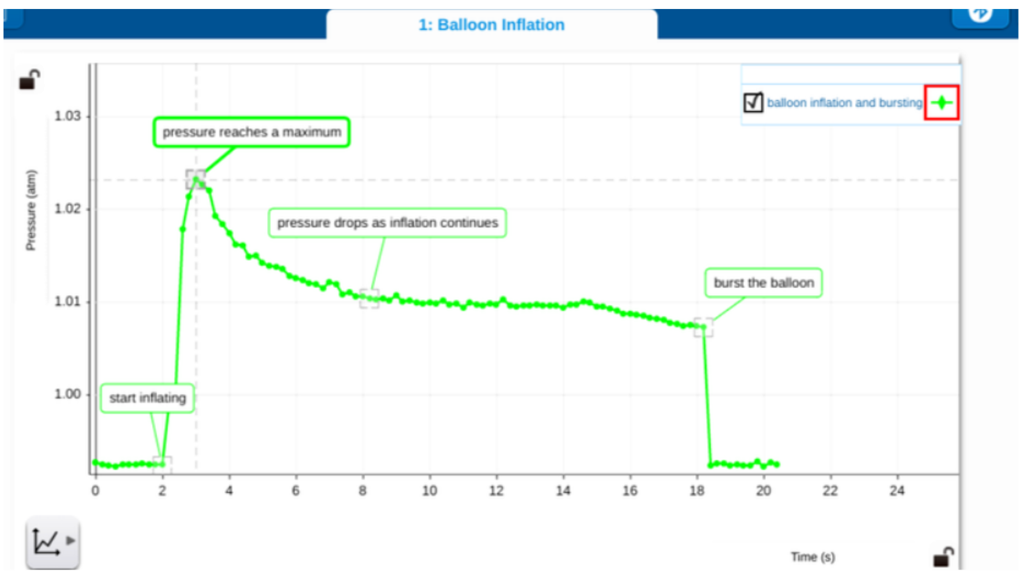
2 W power is too low. Power of hot plate cooker is typically in the range of kilowatt. OR 2 W is power for small LED light bulb (e.g. for refrigerator).

(ii) The speed of a moving electron is 4×10^8 m s^{-1}.

This speed is faster than speed of light, which is 3×10^8 m s^{-1}, so theoretically impossible.

(iii) The pressure of the air in a fully-inflated balloon is 15 000 Pa.

Atmospheric pressure is about 100 000 Pa, so pressure in a balloon must be higher than that.



Graph of internal pressure vs time for a balloon being inflated and then popped.

Source: https://www.mwmresearchgroup.org/the-science-of-balloons-part-1.html