Physical Quantities

Quantities that can be measured or calculated are called Physical Quantities. Example length, force, energy etc.

Non-Physical Quantities are those which cannot be measured. Example, joy, sorrow happiness, sadness, sweet, bitter etc.

7 Basic Physical Quantities

Quantity	SI Base Unit
1. Length	meter (m)
2. Mass	kilogram (kg)
3. Time	seconds (s)
4. Thermodynamic Temperature	Kelvin (K)
5. Electric Current	Ampere (A)
6. Luminous Intensity	candela (cd)
7. Amount of Substance	moles (mol)

Derived Quantities

Any quantity made up using one or more basic quantity is called a <u>derived quantity</u> and its unit is called a <u>derived unit</u>.

e.g. work (J), force (N), power (W), Voltage (V).

Representing Derived Units in Terms of SI Base Units

1. Area

unitless coefficient

$A = l \times b$
$= m \times m$
$= m^2$

$A = \pi r^2$
$= (m)^2$
$= m^2$

$A = 2\pi r h$
$= m \times m$
$= m^2$

2. Volume

$V = l \times b \times h$
$= m \times m \times m$
$= m^3$

$V = \frac{4}{3}\pi r^3$
$= (m)^3$
$= m^3$

$V = \pi r^2 h$
$= (m)^2(m)$
$= m^3$

3. Density

$$\rho = \frac{m}{V}$$
$$= \frac{kg}{m^3}$$
$$= kgm^{-3}$$

4. Velocity / speed

$$v = \frac{s}{t}$$
$$= \frac{m}{s}$$
$$= ms^{-1}$$

5. Acceleration

$$a = \frac{v-u}{t}$$
$$= \frac{ms^{-1} - ms^{-1}}{s}$$
$$= \frac{ms^{-1}}{s}$$
$$= ms^{-2}$$

The resultant quantity is still the same "velocity".

Quantities that have the same units can be added or subtracted!

6. Force

$F = ma$

$= kg.\ ms^{-2}$

$N = kgms^{-2}$

7. Pressure

$P = \frac{F}{A}$

$= \frac{ma}{A}$

$= \frac{kg.\ ms^{-2}}{m^2}$

$= kgm^{1-2}s^{-2}$

$Pa = kgm^{-1}s^{-2}$

$P = \rho gh$

$= kgm^{-3}.\ ms^{-2}.\ m$

$= kg.\ m^{-3+1+1}.\ s^{-2}$

$Pa = kgm^{-1}s^{-2}$

8. Work

$W = F \times s$

$= ma \times s$

$= kg.\, ms^{-2}.\, m$

$J = kgm^2s^{-2}$

9. Energy

$E = mgh$

$= kg.\, ms^{-2}.\, m$

$J = kgm^2s^{-2}$

$E = \frac{1}{2}mv^2$

$= kg.\, (ms^{-1})^2$

$J = kgm^2s^{-2}$

10. Power

$P = \frac{E}{t}$

$= \frac{mgh}{t}$

$= \frac{kg.\, ms^{-2}.\, m}{s}$

$W = kgm^2s^{-3}$

11. Charge

$q = It$

$= A.s$

$C = As$

$A = Cs^{-1}$ ✗ wrong!

12. Voltage

$V = \frac{W}{q}$

$= \frac{F \times s}{q}$

$= \frac{kgms^{-2}.\, m}{As}$

$V = kgm^2s^{-3}A^{-1}$

13. Resistance

$R = \frac{V}{I}$

$= \frac{kgm^2s^{-3}A^{-1}}{A}$

$\Omega = kgm^2s^{-3}A^{-2}$

Determining units of quantities in equations

1. $Q = mc\Delta T$

find the units of 'c' in terms of SI base Units

Q: heat energy　　m: mass

c: spec. heat capacity　　ΔT: temp change

$$c = \frac{Q}{m\Delta T}$$

$$E = mgh$$
$$= kg.ms^{-2}.m$$

$$= \frac{\cancel{kg}m^2s^{-2}}{\cancel{kg}\cdot K} \leftarrow kgm^2s^{-2}$$

$$c = m^2s^{-2}K^{-1}$$

2. $E = \frac{hc}{\lambda}$

find the units of 'h' in terms of SI base Units.

E: energy of photon

h: Plank's constant

c: speed of light

λ: wavelength

$$h = \frac{E\lambda}{c}$$

$$= \frac{kgm^2s^{-2}.\cancel{m}}{\cancel{m}s^{-1}}$$

$$= kgm^2s^{-2-(-1)}$$

$$h = kgm^2s^{-1}$$

3. $F = G\dfrac{m_1 m_2}{r^2}$

F: force between masses
m_1, m_2: mass
r: distance between mass
G: Universal Gravitational Constant

find the units of G.

$$G = \frac{Fr^2}{m_1 m_2}$$

$$= \frac{\cancel{kg}\,ms^{-2}.\,m^2}{\cancel{kg}.\,kg}$$

$$G = m^3 s^{-2} kg^{-1}$$

4. $F = \dfrac{q_1 q_2}{4\pi\epsilon_0 r^2}$

F: force between charges
q_1, q_2: charge
r: distance between
ϵ_0: permitivity of free space.

find the units of ϵ_0

$$\epsilon_0 = \frac{q_1 q_2}{4\pi F r^2}$$

$$= \frac{As.\,As}{kg\,ms^{-2}.\,m^2}$$

$$= A^2.\,s^{2-(-2)}.\,kg^{-1}.\,m^{-3}$$

$$\epsilon_0 = A^2 s^4 kg^{-1} m^{-3}$$

Homogeneity of Equations

All the expression present of either side of the equation must return the same final unit.

1. $T = 2\pi\sqrt{\dfrac{l}{g}}$

l: length
T: time
g: grav. acc.

$$s = \left(\frac{m}{ms^{-2}}\right)^{\frac{1}{2}}$$

$$s = (s^2)^{\frac{1}{2}}$$

$$s = s^{2\times\frac{1}{2}}$$

$$s = s$$

Homogenous Equation

2. $T^2 = \dfrac{4\pi^2 m x}{F}$

T: time
m: mass
x: extension
F: force

$$s^2 = \frac{\cancel{kg}.\cancel{m}}{\cancel{kg}\,\cancel{m}s^{-2}}$$

$$s^2 = s^2$$

Homogenous Equation

3. $s = ut + \frac{1}{2}at^3$

s: displacement
u: initial velocity
t: time
a: acceleration

$m = (ms^{-1})(s) + (ms^{-2})(s)^3$

$m = ms^{-1+1} + ms^{-2+3}$

$m \neq m + ms$

Not Homogenous

4. $P + \rho gh + \frac{1}{2}\rho v^2 = k$

Show that the expressions have the same units. Assuming that the equation is homogenous, find the units of k.

P: pressure
h: depth
ρ: density
v: velocity
g: grav.

$P = \frac{F}{A}$

$P = \frac{kgms^{-2}}{m^2}$

$P = kgm^{-1}s^{-2}$

$kgm^{-1}s^{-2} + (kgm^{-3})(ms^{-2})(m) + kgm^{-3}.(ms^{-1})^2$

$kgm^{-1}s^{-2} + kgm^{-3+1+1}s^{-2} + kgm^{-3+2}s^{-2}$

$kgm^{-1}s^{-2} + kgm^{-1}s^{-2} + kgm^{-1}s^{-2}$

So $k \Rightarrow kgm^{-1}s^{-2}$

Finding Unknown powers of a variable using SI base Units

1. $E_k = \frac{1}{2} m v^x$

$E = mgh$
$= kg.ms^{-2}.m$
$= kgm^2s^{-2}$

$kgm^2s^{-2} = kg.(ms^{-1})^x$

$kgm^2s^{-2} = kg.m^x s^{-x}$

comparing powers of units

m.
$2 = x$
$\boxed{x = 2}$

s.
$-2 = -x$
$\boxed{x = 2}$

$\bullet\ E_k = \frac{1}{2} m v^2 \bullet$

2. $\frac{\Delta m}{\Delta t} = \frac{\pi}{4} \rho d^x v^y$

m: mass
Δt: time
ρ: density
d: diameter
v: velocity

$\frac{kg}{s} = kgm^{-3}.m^x.(ms^{-1})^y$

$m^0 kgs^{-1} = kgm^{-3+x+y}.s^{-y}$

comparing powers of units

m.
$0 = -3 + x + y$
$x + y = 3$

$x + 1 = 3$
$\boxed{x = 2}$

s.
$-1 = -y$
$\boxed{y = 1}$

$\frac{\Delta m}{\Delta t} = \frac{\pi}{4} \rho d^2 v$

3. $v = k \lambda^x E^y \rho^z$

where v: speed of sound
λ: wavelength
E: Young's Modulus (E : $kgm^{-1}s^{-2}$)
ρ: density

k is a unitless coefficient. Find the values of x, y and z. The equation is homogenous.

$$ms^{-1} = (m)^x (kgm^{-1}s^{-2})^y (kgm^{-3})^z$$

$$ms^{-1} = m^x . kg^y m^{-y} s^{-2y} . kg^z m^{-3z}$$

$$kg^0 ms^{-1} = kg^{y+z} . m^{x-y-3z} . s^{-2y}$$

kg.
$$0 = y + z$$

m.
$$1 = x - y - 3z$$

s.
$$-1 = -2y$$

$$\boxed{y = \frac{1}{2}}$$

$$0 = y + z$$

$$0 = \frac{1}{2} + z$$

$$\boxed{z = -\frac{1}{2}}$$

$$1 = x - \frac{1}{2} - 3\left(-\frac{1}{2}\right)$$

$$1 = x - \frac{1}{2} + \frac{3}{2}$$

$$\boxed{x = 0}$$

$$v = k \lambda^0 E^{\frac{1}{2}} \rho^{-\frac{1}{2}}$$

$$v = \frac{k E^{1/2}}{\rho^{1/2}}$$

$$\boxed{v = k\sqrt{\frac{E}{\rho}}}$$

1 The drag force F acting on a moving sphere obeys an equation of the form $F = kAv^2$, where A represents the sphere's frontal area and v represents its speed.

$k = \frac{F}{Av^2} \Rightarrow k = \frac{ma}{Av^2}$

What are the base units of the constant k?

A $\mathrm{kg\,m^{5}\,s^{-4}}$ **B** $\mathrm{kg\,m^{-2}\,s^{-1}}$ **C** $\mathrm{kg\,m^{-3}}$ **D** $\mathrm{kg\,m^{-4}\,s^{2}}$

$k = \frac{kg.ms^{-2}}{m^2.(ms^{-1})^2}$

$k = \frac{kgm\cancel{s^{-2}}}{m^2.m^2\cancel{s^{-2}}}$

$k = kgm^{1-4}$

$k = kgm^{-3}$

2 The table contains some quantities, together with their symbols and units.

$E = mgh$

$= kg.ms^{-2}.m$

$= kgm^2s^{-2}$

quantity	symbol	unit
gravitational field strength	g	ms^{-2} ~~$\mathrm{N\,kg^{-1}}$~~
density of liquid	ρ	$\mathrm{kg\,m^{-3}}$
vertical height	h	m
volume of part of liquid	V	$\mathrm{m^{3}}$

Which expression has the units of energy?

A $g\rho hV$ **B** $\frac{\rho hV}{g}$ **C** $\frac{\rho g}{hV}$ **D** $\rho g^2 h$

$ms^{-2}.kg\cancel{m^{-3}}.m.\cancel{m^3}$

kgm^2s^{-2}

3 The graph shows two current-voltage calibration curves for a solar cell exposed to different light

4 A cylindrical tube rolling down a slope of inclination θ moves a distance L in time T. The equation relating these quantities is

$$L\left(3+\frac{a^2}{P}\right) = QT^2 \sin\theta$$

$3L + \frac{a^2L}{P} = QT^2 \sin\theta$

m m m

Where a is the internal radius of the tube and P and Q are constants.

Which line gives the correct units for P and Q?

	P	Q
A	m^2	$m^2\,s^{-2}$
B	m^2	$m\,s^{-2}$
C	m^2	$m^3\,s^{-2}$
D	m^3	$m\,s^{-2}$

$\frac{a^2L}{P} = m$

$\frac{(m)^2 \cdot (m)}{P} = m$

$P = m^2$

no unit

$QT^2 \sin\theta = m$

$Q(s)^2 = m$

$Q = ms^{-2}$

3 The drag coefficient C_d is a number with no units. It is used to compare the drag on different cars at different speeds. It is given by the equation

$$C_d = \frac{2F}{\rho v^n A}$$

where F is the drag force on the car, ρ is the density of the air, A is the cross-sectional area of the car and v is the speed of the car.

What is the value of n?

A 1 **B** 2 **C** 3 **D** 4

$$= \frac{\cancel{kg}\, m s^{-2}}{\cancel{kg}\, m^{-3} \cdot (m s^{-1})^n (m^2)}$$

$$= \frac{m s^{-2}}{m^{-3} \cdot m^n \cdot s^{-n} \cdot m^2}$$

$$= m^{1-(-3+n+2)} \cdot s^{-2+n}$$

$$= m^{1+3-n-2} \cdot s^{-2+n}$$

$$m^0 s^0 = m^{2-n} \cdot s^{-2+n}$$

m. $0 = 2-n$ $\boxed{n = 2}$

s. $0 = -2+n$ $\boxed{n = 2}$

3 The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ of the liquid. The speed is given by the equation

$$v = k\left(\frac{\Delta P}{\rho}\right)^n$$

where k is a constant that has no units.

What is the value of n?

A $\frac{1}{2}$ **B** 1 **C** $\frac{3}{2}$ **D** 2

$ms^{-1} = \left(\frac{\cancel{kg}m^{-1}s^{-2}}{\cancel{kg}m^{-3}}\right)^n$

$ms^{-1} = (m^{-1+3}s^{-2})^n$

$ms^{-1} = (m^2s^{-2})^n$

$ms^{-1} = m^{2n}s^{-2n}$

comparing

m.

$1 = 2n$

$n = \frac{1}{2}$

s.

$-1 = -2n$

$n = \frac{1}{2}$

$P = \rho g h$

$= kgm^{-3} . ms^{-2} . m$

$P = kgm^{-1}s^{-2}$

2 The unit of resistivity, expressed in terms of base units, is given by

$$\mathrm{kg}\,x^{3}y^{-2}z^{-3}\,.$$

Which base units are x, y and z?

	x m	y A	z s
A	ampere	metre	second
B	metre	ampere	second
C	metre	second	ampere
D	second	ampere	metre

$R = \rho \frac{L}{A}$ $L \rightarrow$ length, $A \rightarrow$ Area

$R = \frac{V}{I}$

$\rho = \frac{RA}{L}$

$R = \frac{W}{qI}$

$\rho = \frac{WA}{qIl}$

$\rho = \frac{F \times s A}{qIl}$

$\rho = \frac{kgms^{-2} \cdot \cancel{m} \cdot m^2}{As \cdot A \cdot \cancel{m}}$

$\rho = \frac{kgm^3s^{-2}}{A^2s}$

$\rho = kgm^3s^{-3}A^{-2}$

3 The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ of the liquid. The speed is given by the equation

$$v = k\left(\frac{\Delta P}{\rho}\right)^n$$

$$ms^{-1} = \left(\frac{\cancel{kg}m^{-1}s^{-2}}{\cancel{kg}m^{-3}}\right)^n$$

$$P = \frac{F}{A} = \frac{kgms^{-2}}{m^2} = kgm^{-1}s^{-2}$$

$$ms^{-1} = (m^2s^{-2})^n$$

$$ms^{-1} = m^{2n}s^{-2n}$$

where k is a constant that has no units.

What is the value of n?

A $\frac{1}{2}$ **B** 1 **C** $\frac{3}{2}$ **D** 2

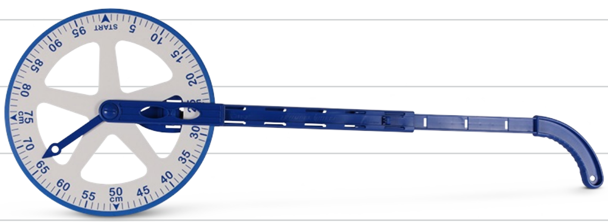
m.
$1 = 2n$
$n = \frac{1}{2}$

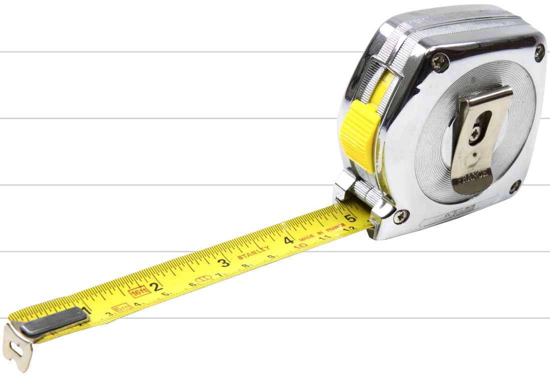
s.
$-1 = -2n$
$n = \frac{1}{2}$

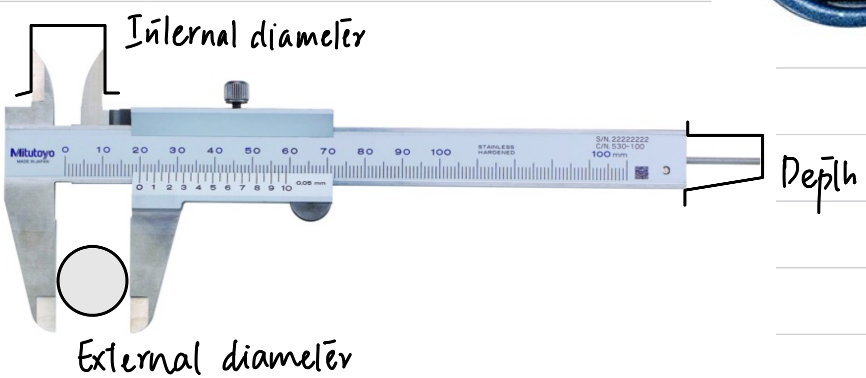
Measurement Techniques

1. Length

	Range	Precision (no. of dp)
Trundle Wheel	several meter	0.1 cm
Measuring Tape	several meter	0.1 cm
Meter Rule	100cm (1m)	0.1 cm
Vernier Caliper	20 ~ 25cm	0.01 cm (0.1 mm)
Micrometer Screw Gauge	~2.5 cm	0.001 cm (0.01mm)
	Range decrease	Precision increase



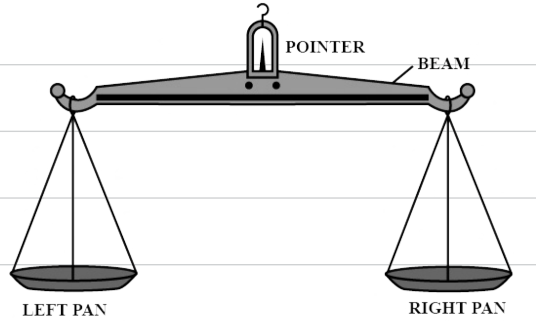




2. Mass

- Electronic Balance
- Beam Balance

Electronic Balance



Beam balance

3. Weight

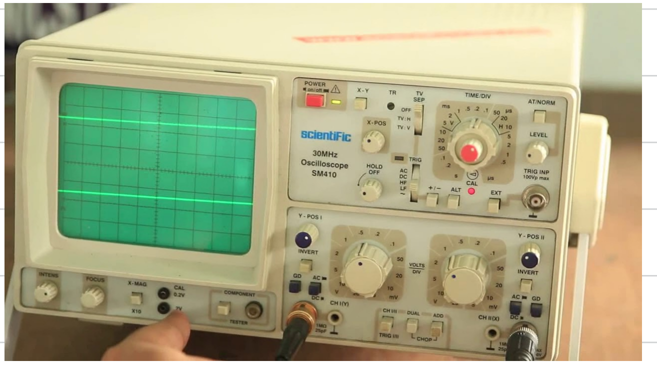
- Newtonmeter / Spring Balance
- Compression balance

Spring Balance

Compression Balance

4. Time

- Stopwatch
- Clock
- CRO



Cathode Ray Oscilloscope

5. Temperature

- Liquid in glass thermometer
- Thermocouple thermometers
- Temperature Sensors

Thermocouple

6. Current

- Ammeter
- Galvanometer
- Multimeter

Ammeter

Galvanometer

Multimeter

7. Voltage

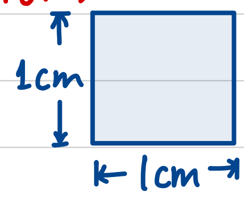
- Voltmeter
- Multimeter

Cathode Ray Oscilloscope (CRO)

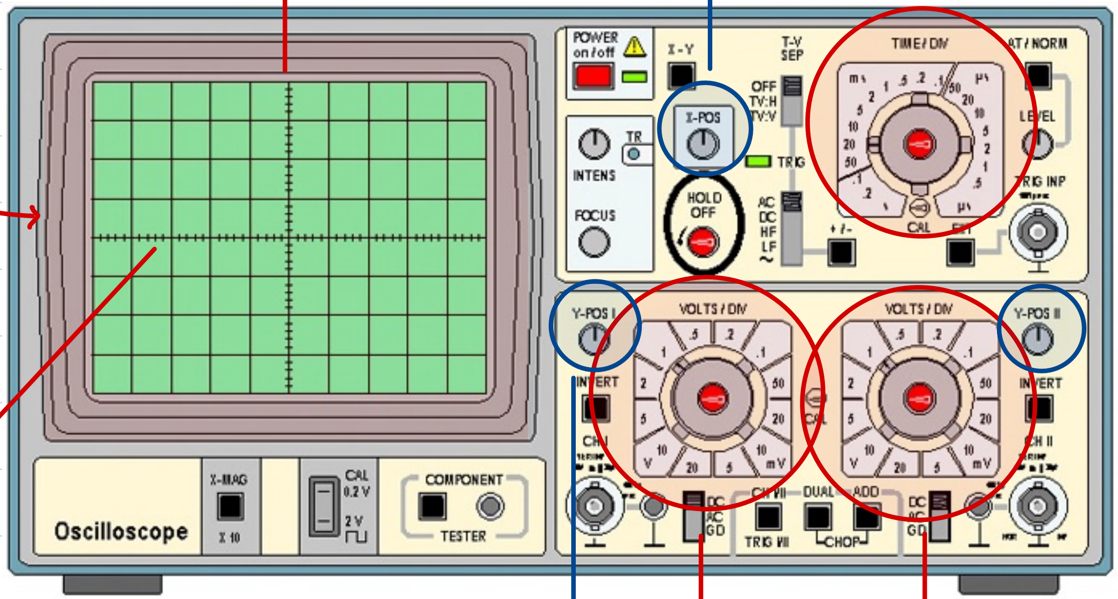
X-axis slide control
translates graph along x-axis

Voltage axis

X-axis
Time base settings
(4ms / division)
(4ms/cm)



Graphical representation of wave signals



Time axis

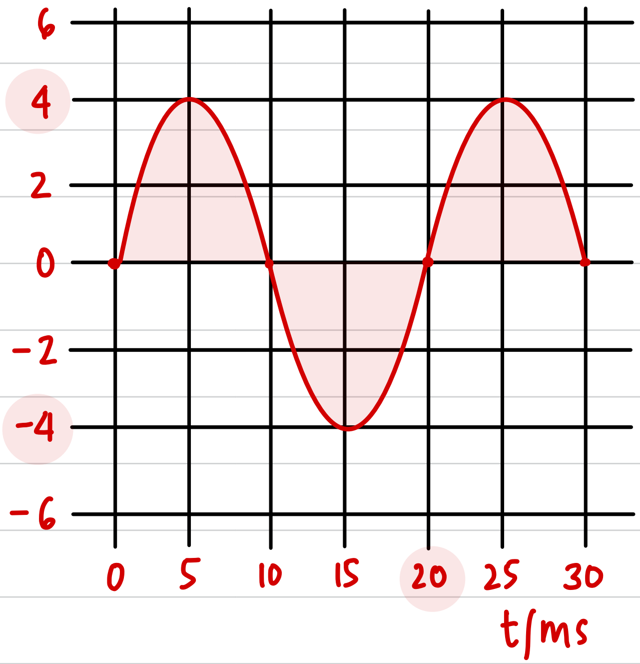
Y-axis slide control
- translates graph along y-axis

Y-axis
Y-gain settings
(2V/ division)
(2V/cm)

Sketch a graph using Information Signal and Settings.

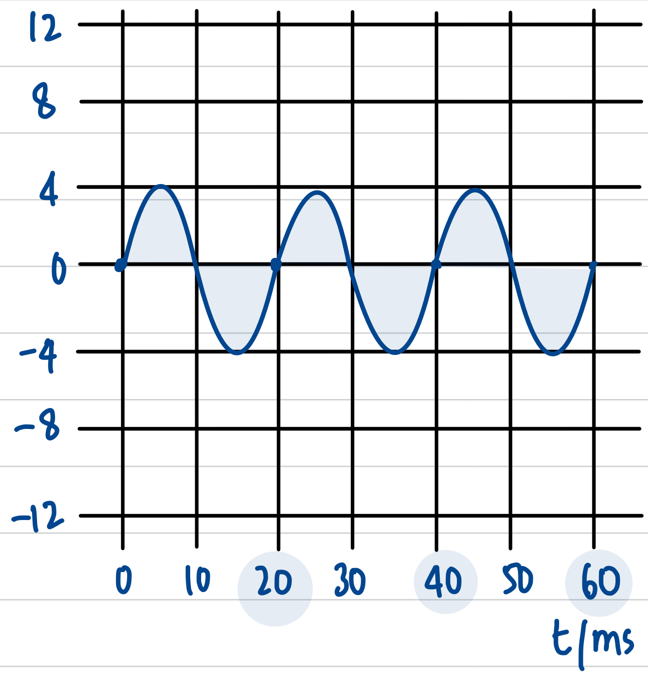
Information Signal

$V_0 = 4.0\,V$
$f = 50\,Hz$
Sine Wave



Setting B

Y-gain : 4 V/div
T-base : 10 ms/div



Setting A

Y-gain : 2 V/div
T-base : 5 ms/div

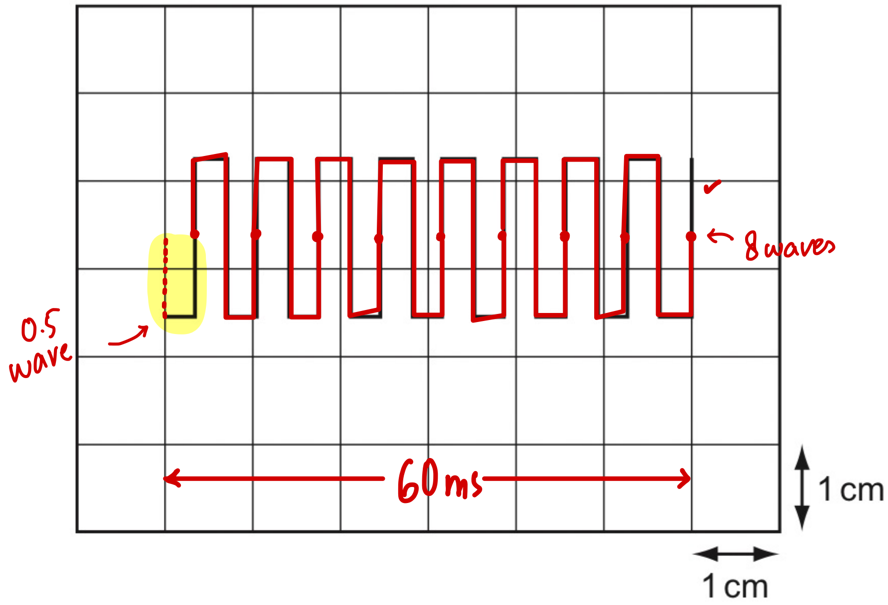
$f = \frac{1}{T}$ $\quad 50 = \frac{1}{T}$

$T = \frac{1}{50} = 0.02\,s$ or $20\,ms$

When the settings of the axis is increased, the graph shrinks along that axis.

Determining frequency and time period from graph & settings

5 The diagram shows a square-wave trace on the screen of a cathode-ray oscilloscope. A grid of 1 cm squares covers the screen. The time-base setting is $10\,\text{ms}\,\text{cm}^{-1}$.



6 boxes × 10 ms

60 ms

8.5 waves — 60 ms

1 wave — x

$x = \frac{60 \times 1}{8.5}$

$x = 7.06$ ms

(Time Period)

$f = \frac{1}{T}$ so $f = \frac{1}{7.06 \times 10^{-3}}$

$f = 141.6$ Hz

8.5 waves – 60 ms

x — 1 s

$x = \frac{8.5 \times 1}{60 \times 10^{-3}}$

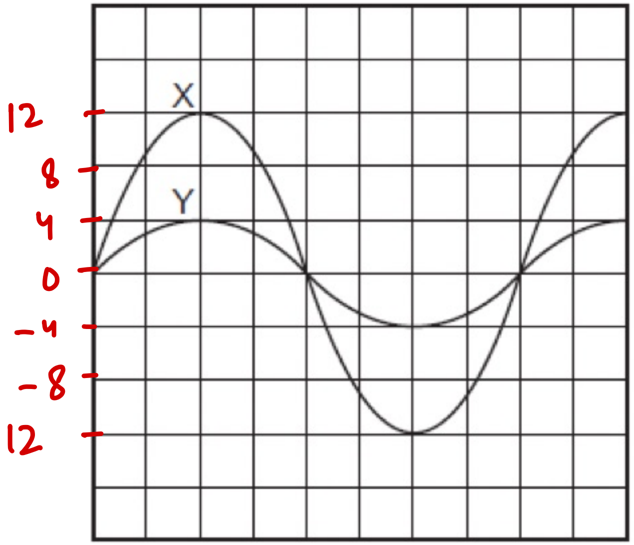
$x = 141.6$ Hz

What is the approximate frequency of the square wave?

A 70 Hz **B** 140 Hz **C** 280 Hz **D** 1400 Hz

Space for working

4 The diagram shows an oscilloscope screen displaying two signals.



$f = \frac{1}{T}$

$50 = \frac{1}{T}$

$T = \frac{1}{50}$

$T = 0.02$

or

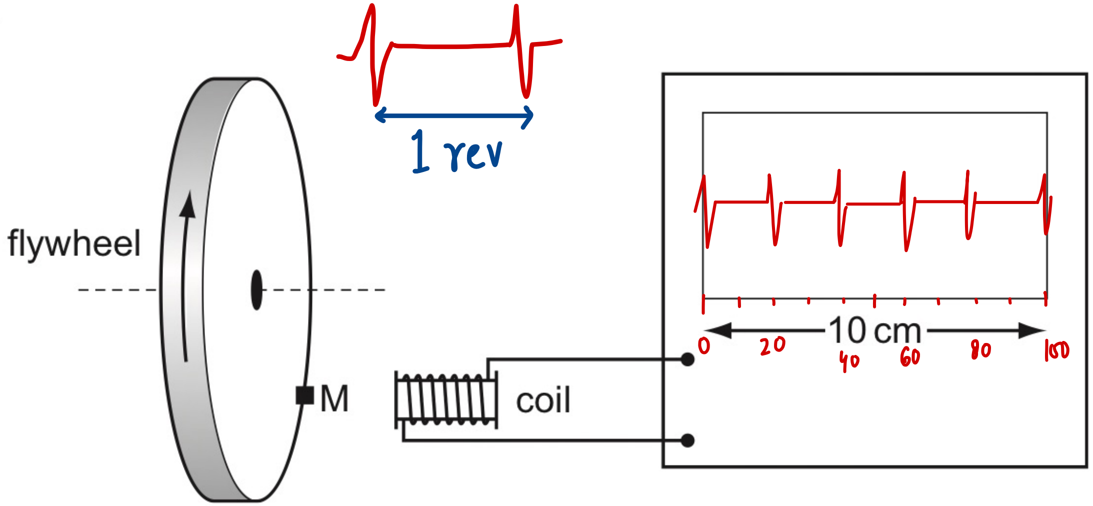
20ms

Signal X has a frequency of 50 Hz and peak voltage of 12 V.

What is the period and peak voltage of signal Y?

	period / ms	peak voltage / V
A	20	4
B	20	12
C	50	4
D	50	12

5 The diagram shows a cathode-ray oscilloscope (c.r.o.) being used to measure the rate of rotation of a flywheel.



3000 rev — 60 s

1 rev — x

$x = \frac{60 \times 1}{3000}$

$x = 0.02$ s or

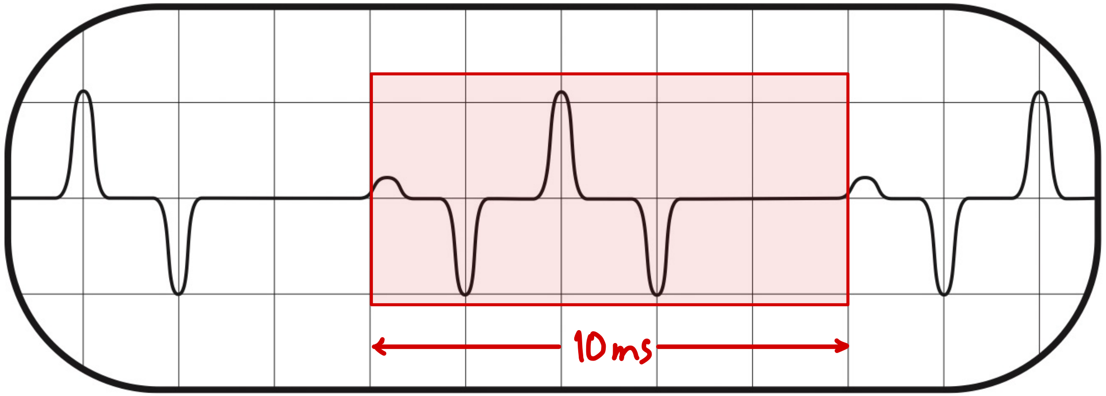
20 ms

The flywheel has a small magnet M mounted on it. Each time the magnet passes the coil, a voltage pulse is generated, which is passed to the c.r.o. The display of the c.r.o. is 10 cm wide. The flywheel is rotating at a rate of about 3000 revolutions per minute.

Which time-base setting will display clearly separate pulses on the screen?

A 1 s cm^{-1} **B** 10 ms cm^{-1} **C** 100 μs cm^{-1} **D** 1 μs cm^{-1}

4 A signal that repeats periodically is displayed on the screen of a cathode-ray oscilloscope.



$f = \frac{1}{T}$

$f = \frac{1}{10 \times 10^{-3}}$

$f = 100\ \text{Hz}$

The screen has 1 cm squares and the time base is set at 2.00 ms cm^{-1}.

What is the frequency of this periodic signal?

A 50 Hz **B** 100 Hz **C** 125 Hz **D** 200 Hz

Unit Conversion

Tera(T) $\times 10^{12}$

Prefix	Exponents
Giga (G)	$\times 10^{9}$
Mega (M)	$\times 10^{6}$
kilo (k)	$\times 10^{3}$
deci (d)	$\times 10^{-1}$
centi (c)	$\times 10^{-2}$
mili (m)	$\times 10^{-3}$
micro (μ)	$\times 10^{-6}$
nano (n)	$\times 10^{-9}$

pico (p) $\times 10^{-12}$

PHYSICAL QUANTITIES AND UNITS

Note: you need to remember the prefix and their exponent to solve the conversion

1. If a prefix is to be inserted, divide the value by the exponent of that prefix.

800m to km $k = 10^3$ $\frac{800}{10^3} = 0.8$ km	48000g to Mg $M = 10^6$ $\frac{48000}{10^6} = 4.8 \times 10^{-2}$ Mg
2.8×10^{-12} s to μs $\mu = 10^{-6}$ $\frac{2.8 \times 10^{-12}}{10^{-6}} = 2.8 \times 10^{-6}$ μs	490×10^{-6} N to mN $m = 10^{-3}$ $\frac{490 \times 10^{-6}}{10^{-3}} = 490 \times 10^{-3}$ 4.90×10^{-1} 0.490 mN

2. If a prefix is to be removed, multiply the value by the exponent of that prefix.

6700 μs to s $\mu = 10^{-6}$ 6700×10^{-6} 6.7×10^{-3} s	30 MN to N $M = 10^6$ 30×10^6 3.0×10^7 N
6.05×10^{-6} nJ to J $n = 10^{-9}$ $6.05 \times 10^{-6} \times 10^{-9}$ 6.05×10^{-15} J	48000 mV to V $m = 10^{-3}$ 48000×10^{-3} 48 V.

3. If a prefix is to be replaced by another, combine both rules.

5000 µs to ms $\mu : 10^{-6}$ $m : 10^{-3}$ $\frac{5000 \times 10^{-6}}{10^{-3}}$ 5 ms	65 kN to dN
8.85 x 10^{-12} GJ to µJ	6.7 x 10^{-5} mC to MC

When calculating answers from given data, give your answers in the least no. of significant figures as in your data or one more than that.

Example: $x = 27.54$ (4 s.f) $y = 33$ (2 s.f.) if $z = x \times y$ so

$z = 27.54 \times 33$ either or

$z = 908.82$ (5 s.f.) Answer ⇒ 910 (2 sf) 909 (3 sf)

PRECISION VS ACCURACY

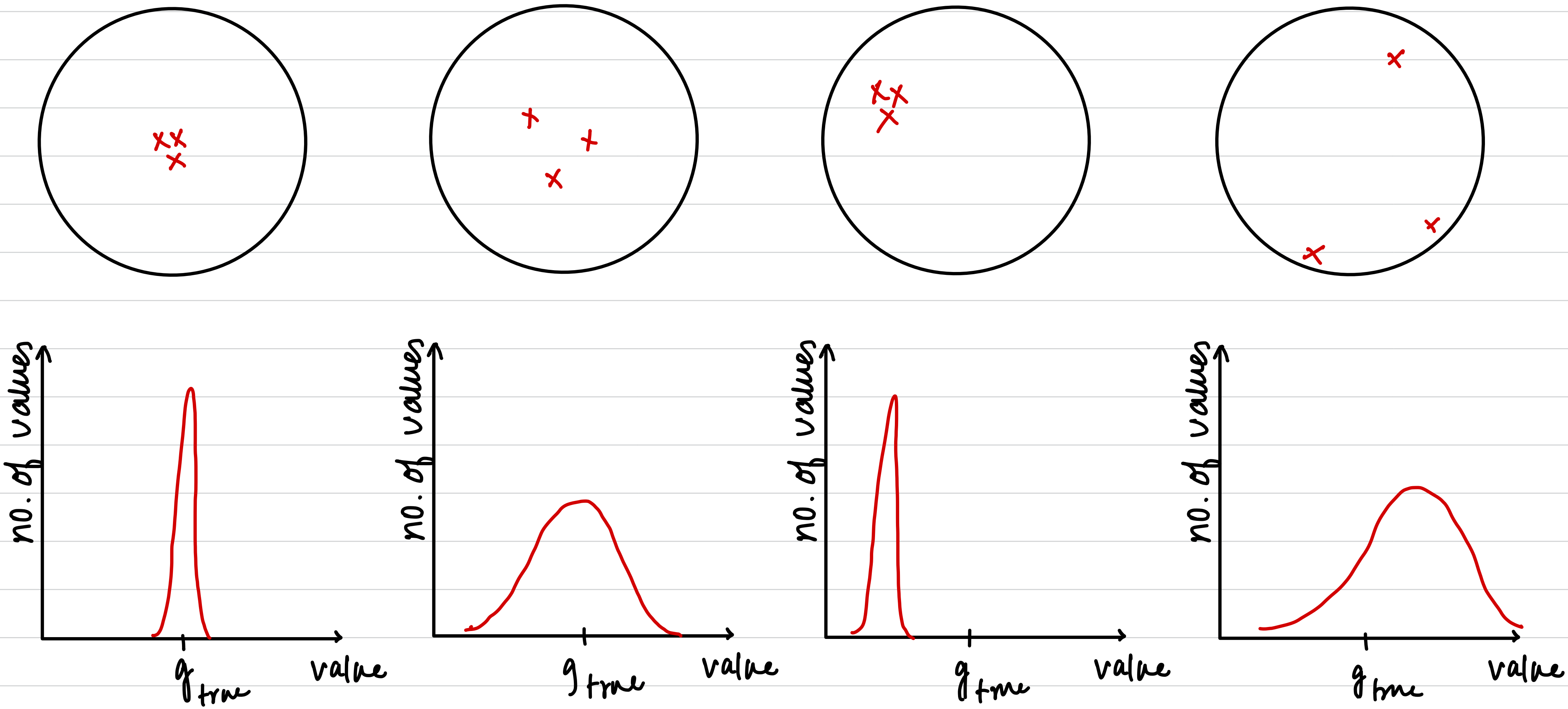
Precision: It tells how close the values are to one another.
No. of decimal places of a value helps improve precision.

e.g. 4.2, 3.9, 4.1 (precise)
4.2, 2.1, 6.8 (not precise) "Scattered data"

Accuracy: It tells how close the values are to the true value.
Accuracy depends upon the quality of experiment performed to determine values.

e.g. g (true value) = 9.8 ms^{-2}

Student A: g = 9.6, 10.2, 9.5 (Accurate)
Student B: g = 7.1, 5.5, 9.3 (Not Accurate)



Both Accurate and Precise

Accurate but not precise

Not Accurate but precise

Neither Accurate Nor precise

Error & Uncertainty

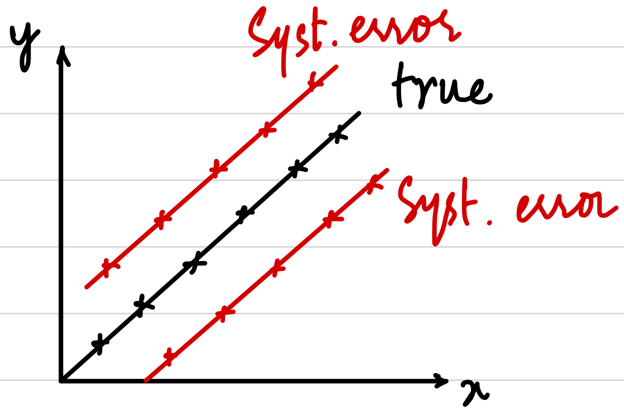
Error

The difference in the true value and the obtained value during experiment.

$$\text{Error} = |\text{true value} - \text{obtained value}|$$

Types of Error

i. Systematic Error: Error introduced due to the fault in method of experiment, instrument used or equation adopted while performance.



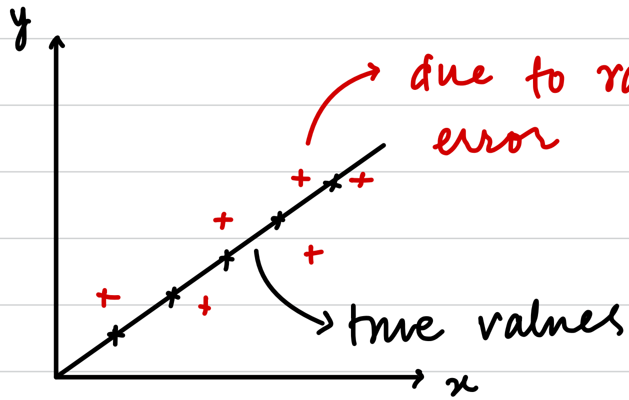
They cannot be removed by repeat & average.

- Systematic Error causes offset of data on either side of the true value.
- Reduces Accuracy.

To eliminate systematic error, find out the problem in experiment and correct it ii, Random Error

- Error introduced due to the fluctuations going on it surrounding e.g. temperature, wind speed, humidity etc. It may also occur due to human reaction time error.

- They can be removed / reduced by repeat and average.



- Random errors create scatter on both sides of the true value.

- Reduce precision.

Uncertainity

- It is the margin of doubt present in the results obtained during experiment.

- Example :

values of g calculated are 10.9, 10.5, 10.2, 9.8, 9.4, 9.6, 9.0

average value of g = $\frac{\Sigma g}{n} = \frac{10.9 + 10.5 + 10.2 + 9.8 + 9.4 + 9.6 + 9.0}{7}$

$g_{avg} = 9.9\ N\,kg^{-1}$

$$\boxed{\text{Uncertainity} = \frac{\text{max value} - \text{min value}}{2}}$$

so $\Delta g = \frac{10.9 - 9.0}{2}$

$\Delta g = 1.0$

so the value of g is quoted as $g = 9.9 \pm 1.0$

→ Uncertainity reflects the precision of your experiment or results.
• less precision ⟶ more scattered data ⟶ high uncertainity

→ Instruments that have more precision i.e. give values to more no. of d.p. incur less uncertainity in your results.

Rules for writing uncertainity with principle value

9.9 ± 0.1

Principle value — Uncertainity

1. No. of d.p in your uncertainity should be either "equal to" or "less than" the no. of d.p in principle value.

9.9 ± 0.95 ✗
9.9 ± 1.0 ✓
9.9 ± 1 ✓

2. In case of exponents i.e. 10^x, both principle value and uncertainity should have the same power of exponent.

$5.96 \times 10^{12} \pm 1.23 \times 10^{11}$ ✗
$5.96 \times 10^{12} \pm 0.123 \times 10^{12}$ ✗
$5.96 \times 10^{12} \pm 0.12 \times 10^{12}$ ✓

Representation of Uncertainity

Absolute Uncertainity

Δx

12.0 ± 0.1

Absolute Uncertainity

Fractional Uncertainity

$\frac{\Delta x}{x}$

$\frac{0.1}{12.0} = 0.0083$

Percentage Uncertainity

$\Delta x\% = \frac{\Delta x}{x} \times 100$

$\frac{0.1}{12.0} \times 100 = 0.83\%$

Rules of Uncertainity

1. Addition & Subtraction

$y = a + b$

$y = a - b$

$$\boxed{\Delta y = \Delta a + \Delta b}$$

$a = 12.0 \pm 0.2$

$b = 4.0 \pm 0.1$

$\Delta y = \Delta a + \Delta b$

$= 0.2 + 0.1$

$\Delta y = 0.3$

$y = a + b$

$y = 16.0$

$y = 16.0 \pm 0.3$ Ans

$y = a - b$

$y = 8.0$

$y = 8.0 \pm 0.3$ Ans

2. If a coefficient is multiplied with a variable having power of "1".

$y = na$ where n is a coefficient

$$\boxed{\Delta y = n\,\Delta a}$$

if $y = 3a$ so $\Delta y = 3\Delta a$

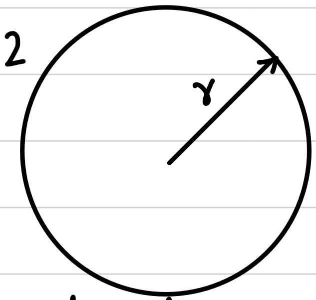
$y = 3a$

$y = a + a + a$

$\Delta y = \Delta a + \Delta a + \Delta a$

$\Delta y = 3\Delta a$

let $r = 2.53 \pm 0.02$



find the value of circumference along with its uncertainty.

$C = 2\pi r$

$C = 2\pi(2.53)$

$C = 15.89 \simeq 15.9$

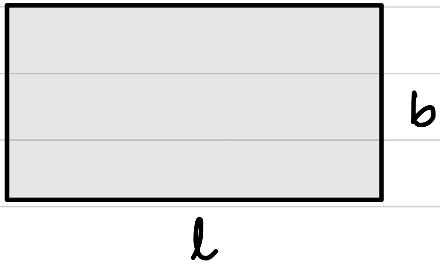
$\Delta C = 2\pi\,\Delta r$

$\Delta C = 2\pi(0.02)$

$\Delta C = 0.12$

$C = 15.9 \pm 0.1$

$l = 15.4 \pm 0.1$ cm
$b = 9.5 \pm 0.1$ cm



Find the value of Perimeter along with its uncertainity.

$P = 2(l + b)$

$P = 2(15.4 + 9.5)$
$P = 49.8$ cm

$P = 2(l + b)$
$P = 2l + 2b$

$\Delta P = 2\Delta l + 2\Delta b$

$P = l + l + b + b$
$\Delta P = \Delta l + \Delta l + \Delta b + \Delta b$
$\Delta P = 2\Delta l + 2\Delta b$

$\Delta P = 2(0.1) + 2(0.1)$
$\Delta P = 0.4$ cm

$P = (49.8 \pm 0.4)$ cm

3. If variables are being multiplied or divided

$y = a \times b$ or $y = \dfrac{a}{b}$

$$\boxed{\Delta y\% = \Delta a\% + \Delta b\%}$$

$$\frac{\Delta y}{y} \times 100 = \frac{\Delta a}{a} \times 100 + \frac{\Delta b}{b} \times 100$$

$$\frac{\Delta y}{y} \times \cancel{100} = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right) \times \cancel{100}$$

$$\boxed{\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b}}$$

<u>Example #1</u>

$b = 3.0 \pm 0.2$

$l = 12.0 \pm 0.1$

Find the area along with its uncertainty.

$A = l \times b$

$A = 12 \times 3$

$A = 36.0\,cm$

$$\frac{\Delta A}{A} = \frac{\Delta l}{l} + \frac{\Delta b}{b}$$

$$\frac{\Delta A}{36} = \frac{0.1}{12} + \frac{0.2}{3}$$

$\Delta A = 2.7\,cm$

$A = 36.0 \pm 2.7\,cm^2$

$A = 36 \pm 3\,cm^2$

$\Delta A\% = \Delta l\% + \Delta b\%$

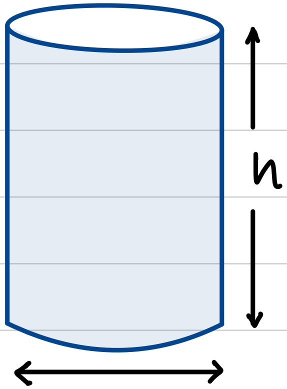
$$\Delta A\% = \left(\frac{\Delta l}{l} + \frac{\Delta b}{b}\right) \times 100$$

$$\Delta A\% = \left(\frac{0.1}{12} + \frac{0.2}{3}\right) \times 100$$

$\Delta A\% = 7.5\%$

Example # 2

Find the surface Area along with its uncertainity



$h = 15.0 \pm 0.1\,cm$

$d = 2.61 \pm 0.02\,cm$

$A = 2\pi r h$

Example #3

$v = \frac{s}{t}$, where v: velocity s: displ. t: time

Given that s: 53.6 ± 0.1 cm
t: 2.53 ± 0.02 s

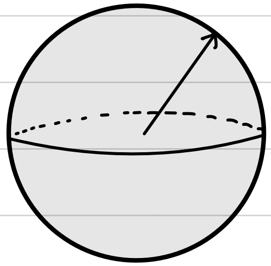
Calculate the value of "v" along with its uncertainity.

4. If a variable has a power other than 1

$y = a^n$ so $\boxed{\Delta y\% = n \Delta a\%}$

OR

$$\boxed{\frac{\Delta y}{y} = n \frac{\Delta a}{a}}$$



Example #1

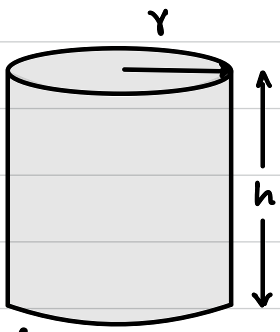
$r = 2.61 \pm 0.01$ mm

Calculate the volume of sphere along with its uncertainty.

$$V = \frac{4}{3} \pi r^3$$

Example #2 (Combining Rules)

$r = 4.63 \pm 0.01$ cm
$h = 25.6 \pm 0.2$ cm



Calculate the volume of the cylinder along with its
i. absolute uncertainity
ii. percentage uncertainity

$$V = \pi r^2 h$$