PHY101 Short Notes

Physics ↔ study of nature

(figure 1.2)

Matter is studied at all levels: macroscopic → microscopic
e.g. gold cube → atoms → nuclei → quarks

Also, the different forces that are predominant at these different levels:

gravitational → electric → strong → weak

Tools for our investigations: Units

Standard units ***SI*** (System International)

- Length m (meter)
- Mass kg (kilogram)
- Time s

(second) Also, Gaussian ***CGS***

- cm (centimeter)
- g (gram)
- s (second)

And British Engineering (or US Customary units) ***BE***

- ft (feet)
- sl (slugs)
- s (seconds)

→ need conversion of units: 1 inch ≈ 2.54 cm
1 foot ≈ 0.3 m
...
etc.
1 pound = 4.45 N (Force!)

Other units are derived from these: eg. 1 Newton = 1 $\frac{kg * m}{s^2}$ ….

<u>Examples:</u>

1.) 1019.5 km/hr → m/s?

$$1019.5\, km/hr * \frac{10^3\, m}{1\, km} * \frac{1\, hr}{3600\, s} = 283.2\, m/s$$

2.) 70 mi/hr → m/s?

$$70\, mi/hr * \frac{1609\, m}{1\, mi} * \frac{1\, hr}{3600\, s} = 31\, m/s$$

It's necessary to check the units for <u>consistency</u>.

eg: area [A] = L^2 → [A] = [m^2]

velocity [v] =

→ [v] =

$\frac{[m]}{[s]}$

Review of <u>Powers of Ten</u>

$10^0 = 1$,

$10^1 = 10$,

...

$10^{-1} = \frac{1}{10} = 0.1$,

$10^{-2} = \frac{1}{100} = 0.01$,

..

& Prefixes:

kilo (k) → 10^{3}	mega (M) → 10^{6}	giga (G) → 10^{9}	tera (T) → 10^{12}
milli (m) → 10^{-3}	micro (μ) → 10^{-6}	nano (n) → 10^{-9}	pico (p) → 10^{-12}

Lengths

distance to the farthest quasar	10^{26} m
“ a galaxy	$\sim 10^{21}$ m
“ the nearest star	4×10^{16} m
“ Pluto	6×10^{12} m
diameter of the Sun	$\sim 10^{9}$ m
radius of the Earth	$\sim 6 \times 10^{6}$ m
Mt. Everest	9×10^{3} m
Statue of Liberty	10^{2} m
man	~ 1 m
computer chip	10^{-3} m
red blood cell	10^{-5} m
length of virus	10^{-8} m
radius of atom	10^{-10} m
radius of nucleus	10^{-15} m

Time

Age of universe	$\sim 5 \times 10^{17}$ s
Age of pyramids	$\sim 10^{11}$ s

Human life expectancy (US)	~2 x 10^9 s
A day	9 x 10^4 s
Time between heartbeats	8 x 10^{-1} s
Flapping of housefly wings	~10^{-3} s
Lifetime of μ	2 x 10^{-6} s
Time required for a microprocessor to execute an instruction	~2 x 10^{-9} s
Fastest transistors (operation time)	~10^{-12} s
Lifetime of most unstable particles	~10^{-23} s

Uncertainty (accuracy) in measurement – related to the sensitivity of the apparatus

eg. using a meter stick → 1 mm

vs. a caliper → 0.1 mm

vs. a micrometer → 0.01 mm

Significant Figures

A significant figure is a reliably known digit.

eg. measure the area of a rectangular plate using a meterstick.

Accuracy: ± 1 mm or ± 0.1 cm

Measure: L = (16.3 ± 0.1) cm i.e. 16.2 ↔ 16.4 cm

Similarity: W = 4.5 cm (± 0.1 cm) i.e. 4.4 ↔ 4.6 cm

→ in our case: 16.3 has 3 sig. figs.
4.5 has 2 sig. figs.

If we now calculate the area:

A = L x W = (16.3 cm) (4.5 cm) = 73.35 cm^2
the answer, though, is = 73 cm^2 (2 sig. figs.)

Notice that the area actually varies from: (16.2) (4.4) = 71.28 $cm^3 \rightarrow 71\ cm^2$

to: (16.4) (4.6) = 75.44 $cm^3 \rightarrow 75\ cm^2$

that is

$A = (73 \pm 2)\ cm^2$

Multiplying and dividing:

Round to the number of significant figures as the number w/ fewest significant figures.

eg. $d = ½\ gt^2 = ½\ (9.81\ m/s^2)\ (3.1\ s)^2 = 47.14\ m \rightarrow 47\ m$
constant^ ^3 Sig. Figs. ^2 Sig. Figs.

Adding and subtracting:

Number of decimal places equals the smallest number of decimal places.

eg. 123 + 5.35 = 128
^0 dec. ^2 dec.

Problem solving:

Carry more digits in the calculations (for better precision) then round to the correct number of significant figures at the end.

Zeroes may not count

e.g. 0.0175 has 3 significant figures

3500 is ambiguous

Better to use the scientific notation:

3.5×10^3 has 2 significant figures

3.5×10^3 has 3 significant figures

Similarly,

1.75×10^{-2} …

~ 0.00015 → 1.5×10^{-4} has 2 significant figures while 1.50×10^{-4} has 3 significant figures

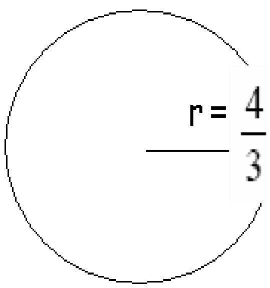
Order – of – Magnitude Calculations are at times necessary to make an estimate when details are not available.

e.g. Estimating the number of galaxies in the universe

Data – astronomers can see ~10 billion light years into space

- our local group: 14 galaxies
- distance to the next local group: 2 million light years

[1 light year = distance traveled by light in one year ≈ 9.5 x 10^{15} m]



$$\frac{4}{3}\pi r^3 \simeq (10^6 ly)^3 = 10^{18} ly^3$$ **Volume =**

required to describe position and motion of objects.

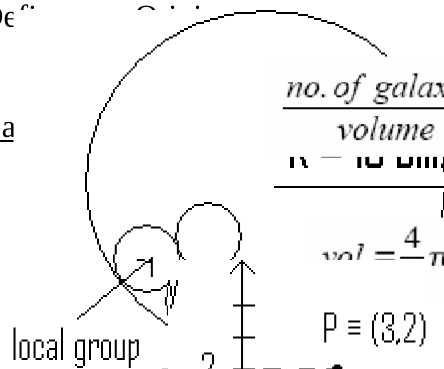
De... O...

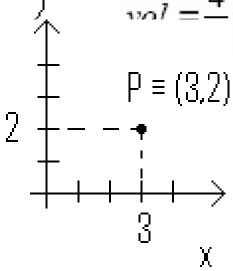
Ca...

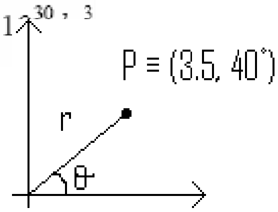
$$\frac{no.\ of\ galaxies}{volume}$$

$$no.\ of\ galaxies = \left(\frac{no.\ of\ galaxies}{ly^3}\right) vol. \simeq \left(\frac{10^{-17}}{l^3}\right)(10^{30} ly^3) = 10^{13}\ galaxies$$

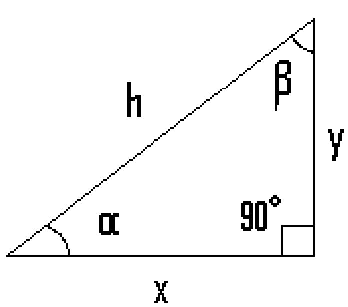
$$vol = \frac{4}{3}\pi R^3 \simeq (10^{10} ly)^3 \simeq 1...^{30}\ ...^3$$







Trigonometry – Review



h = hypotenuse

side x is adjacent to α

side y is opposite to α

$x = h\cos(\alpha) \rightarrow \cos(\alpha) = x/h$

$y = h\sin(\alpha) \rightarrow \sin(\alpha) = y/h$

$\tan(\alpha) = y/x$

$\beta = 90^{\circ} - \alpha \rightarrow \sin(\beta) = x / h$

$\cos(\beta) = y / h$

$\tan(\beta) = x / y$

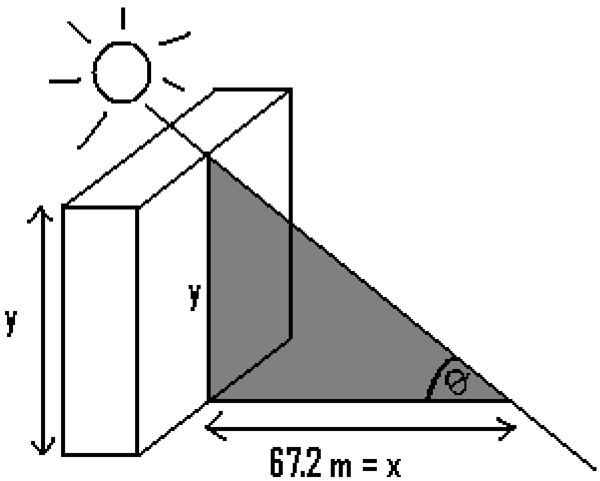
If we know cos(α) or sin(α), etc. then:

$\alpha = \sin^{-1}(y / h)$ $\alpha = \cos^{-1}(x / h)$ $\alpha = \tan^{-1}(y / x)$

<u>Pythagorean Theorem</u>:

$$h^2 = x^2 + y^2 \qquad h = \sqrt{(x^2 + y^2)}$$

Example 3: shadow of tall building is 67.2 m (x), θ = 50.0º



Find the height (y) of the building.

y / x = tan(θ)

y = (tan(θ))x = tan(50.0º)(67.2m) = 80.0 m

Converting from Cartesian to polar coordinates:

P ≡ (x,y) = (-3.50, -2.50) m

Find (r , θ).

$$r=\sqrt{(x^2+y^2)}=\sqrt{((-3.50\,m)^2+(-2.50\,m)^2)}=4.30\,m$$

$$\tan(\theta)=\frac{y}{x}=\frac{-2.50\,m}{-3.50\,m}=0.714$$

$$\theta=\tan^{-1}(0.714)=35.5°+180°=216°$$

Polar to Cartesian coordinates:

P ≡ (r, θ) = (5.00 m, 37.0°)

Find (x, y).

x = r cos(θ) = (5.00 m) cos(37°) = 3.99 m

y = r sin(θ) = (5.00 m) sin(37°) = 3.01 m