Physics Notes for MYCT

Topic 1 & 2 – Physical Quantities, Units and Measurement Techniques

Accuracy vs. Precision

Definition of Accuracy: Refers to how close measured value is to true/accepted value

Definition of Precision: Refers to how close a group of measurements are to one another

Table of differences between both terms

Accuracy	Precision
Measured by the closeness of the measurement to true value	Measured by the closeness of measurements to one another (Reproducibility)
Can be determined with one reading	Requires multiple readings to be determined
Depends on how good the result is	Depends on how good the instrument is
Enhanced when systematic error is reduced	Enhanced when random error is reduced
Related to error	Related to uncertainty

Examples of systematic errors – zero error, incorrect calibration

*Note: Can only be either above or below true value

Examples of random error – parallax errors, reaction time, background noise

*Note: Can be either above or below true value

Recording measurements to correct precision

A measurement is usually recorded to the smallest half division of the smallest scale of the instrument (e.g. ammeter reading, voltmeter reading, and measuring cylinder reading).

However, when taking measurements that involve intervals, we record to the smallest division (e.g. measuring length using meter rule or protractor).

SI Units

Seven SI base units

Base Quantity	**Base Unit**	**Symbol**
Length	Meter	m
Mass	Kilogram	Kg
Time	Second	S
Current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous Intensity*	Candela	cd

* not in syllabus

SI Derived Units

Quantity	Common Units	Derived Unit
Volume	m^3	m^3
Density	$kg\ m^{-3}$	$kg\ m^{-3}$
Acceleration	$m\ s^{-2}$	$m\ s^{-2}$
Force	$kg\ m\ s^{-2}$	Newton (N)
Work Done	$kg\ m^2\ s^{-2}$	Joules (J)

SI Prefixes

Prefix	Symbol	Multiply the base by
Exa-	E	1×10^{18}
Peta-	P	1×10^{15}
Tera-	T	1×10^{12}
Giga-	G	1×10^{9}
Mega-	M	1×10^{6}
Kilo-	k	1×10^{3}
Hector-	H	1×10^{2}
Deca-	da	1×10^{1}
Deci-	d	1×10^{-1}
Centi-	c	1×10^{-2}
Milli-	m	1×10^{-3}
Micro-	µ	1×10^{-6}
Nano-	n	1×10^{-9}
Pico-	p	1×10^{-12}
Femto-	f	1×10^{-15}
Atto-	a	1×10^{-18}

*Note: 10^{-10} m = 1 ängstrom

Significant Figures (s.f.)

If a number **DOES NOT** have a decimal point and the right most digit is 0, then the number of significant figures it has is unclear.

E.g.: 20 cm – It can be interpreted as having 2 s.f. (nearest unit) because it happened to be exactly 20 cm. However, it can also be interpreted as having one 1 s.f.(nearest 10) because its actual value could have been 18 cm and was rounded off to the nearest 1 s.f.

Examples of numbers written to 1, 2 and 3 significant figures are shown in the table below:

One s.f.		Two s.f.		Three s.f.	
Value	Limits of Accuracy	Value	Limits of Accuracy	Value	Limits of Accuracy
3	Between 2 and 4	3.0	Between 2.9 and 3.1	3.00	Between 2.99 and 3.01
0.3	Between 0.2 and 0.4	0.30	Between 0.29 and 0.31	0.300	Between 0.299 and 3.01
3×10^2	Between 200 and 400	3.0×10^2	Between 290 and 310	3.00×10^2	Between 299 and 301

Calculating with significant figures

The general rule is to round the answer to the least precise measurement used in calculation.

Use the least no. of decimal places when dealing with addition/subtraction.

Use the least no. of significant figures when dealing with multiplication/division.

*Note: Only do this on the final step.
**Note: Only use this when discussing the 1st and 2nd topics. For the rest, round off to3 s.f. when multiplying and dividing, but use the least no. of d.p. when adding/subtracting.

Instruments and Zero Errors

Vernier Calipers

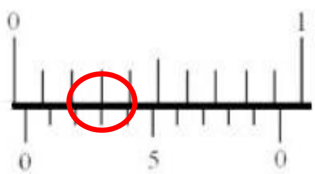
- Precision is to 0.1 mm

Micrometer Screw Gauge

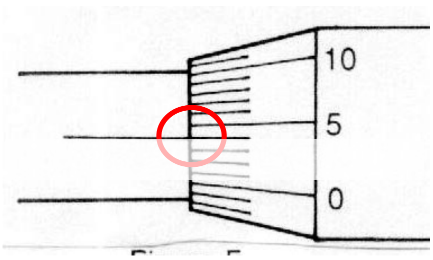
- Precision is to 0.01 mm

*Note: You should know how to use them by now.

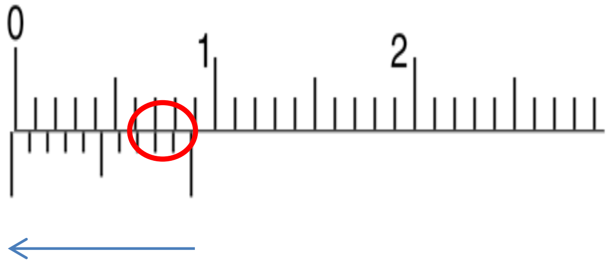
Positive Zero Error

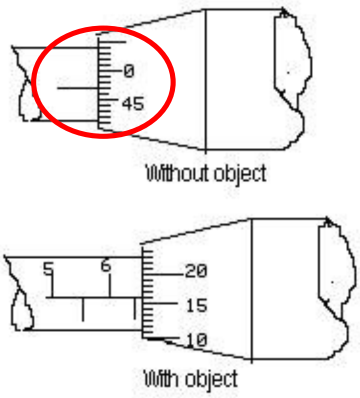


positive zero error



Negative Zero Error





*Note: For negative zero errors, count backwards. E.g.: in the vernier callipers diagram above, the 0.8 mm line is touching the 8 mm line. Hence, the negative error is -0.2 mm because you count in the way indicated by the arrow.

Topic 3 – Waves

Definition of a wave: A disturbance that travels through a medium from one location to another. Waves can be considered energy transport phenomena because energy is transported from one location to the other. A wave transports energy without transporting matter.

Mechanical waves require a medium through which they propagate.

Definition of a medium: A physical substance through which mechanical waves pass through.

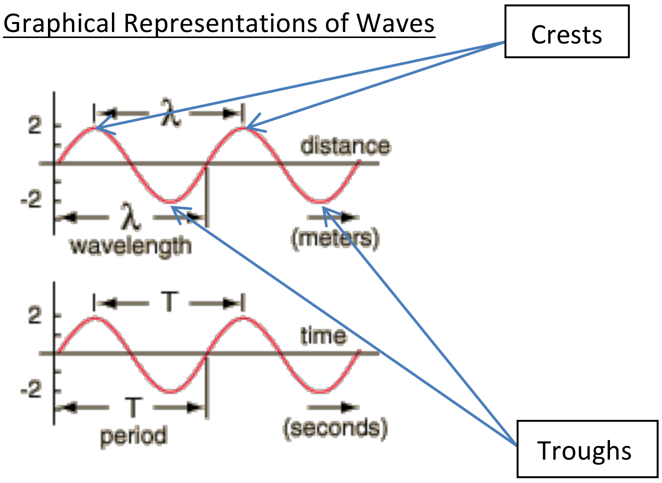
Electromagnetic waves do not require any medium, and hence can propagate through vacuum.

Table of Definitions:

Term	Definition
Displacement	Distance of the oscillating particle in a wave from its equilibrium position at any instant
Amplitude	Maximum displacement of the oscillating particle in a wave from the equilibrium position
Period (T)	Time taken to complete one oscillation of the wave
Frequency (f)	Number of oscillations made by the wave per unit time. Unit of f is generally Hertz (Hz)
Wavelength (λ)	Distance between corresponding points in successive waveforms. E.g.: Distance between 2 successive crests/troughs

In phase	A set of points are said to be in phase if they have the same displacement and are moving in the same direction *Note: Points within a wavelength cannot be in phase. Two successive points that are in phase are exactly one wavelength apart.

Graphical Representations of Waves



*Note: The y-axis for both graphs is displacement

Formulas to take note of

$f = \frac{1}{T}$ (where f is frequency and T is the period)

$v = \frac{\lambda}{T}$ (where v is speed, λ is the wavelength and T is the period)

$v = f\lambda$ (where v is speed, f is frequency and λ is the wavelength)

Substitute in 1st equation into 2nd to get 3rd.

Transverse vs. Longitudinal Waves

Definition of a transverse wave: Wave in which particles of the medium move in a direction perpendicular to the direction of travel of the wave.

Examples: Electromagnetic waves, seismic S waves

Definition of a longitudinal wave: Wave in which particles of the medium move in a direction parallel to the direction of travel of the wave.

Examples: Sound waves

*Note: Refer to the video (http://www.youtube.com/watch?v=Rbuhdo0AZDU) for visual representation.

Refraction of Waves

Waves move fast in deep water → longer wavelengths
Waves move slow in shallow water → shorter wavelength

*Note: Deep water is seemingly denser than shallow water.

Topic 4 – Sound and C.R.O

Definition of Sound Waves & Characteristics

Sound waves are:

- Longitudinal waves
- Comprise series of compressions and rarefactions
- Propagate energy from one point to another without transporting matter
- Produced by the vibration of some objects

*Note: Sound cannot travel in vacuum.

Speed of sound

Factors affecting speed of sound:

1. Probability of particle collision to propagate energy
    a. Particle arrangement/strength of interatomic forces (medium)
    b. Speed of individual particles (temperature of medium)

*Note: wave speeds are dependent only on the medium. Hence, the speed of the wave will be the fastest in a solid as the particles are very closely packed, which means that there is a greater probability of particles colliding with one another and thus transmitting energy.

Speed of Sound vs. Temperature

When temperature ↑, probability of particle collision ↑.
Hence, wave speed ↑.

Speed of Sound vs. Humidity

When humidity ↑, more water molecules in the air ↑.
Hence, wave speed ↑.

Speed of Sound vs. Wind Conditions

When wind is in same direction as sound:

$V_{moving\ air} > V_{still\ air}$

When wind is in opposite direction as sound:

$V_{moving\ air}\ V_{still\ air}$

Pitch/Loudness of Sound

The loudness of sound is dependent on the amplitude of the wave. Hence, a sound wave with greater amplitude will be louder in volume.

The pitch of sound is dependent on the frequency of the wave. Hence, a sound wave with a greater frequency will be higher in pitch.

Ultrasound

The range of audible frequencies for an average human is between 20 Hz and 20 kHz. The range decreases as we get older and our ears lose their sensitivity to the extreme end of the range.

Sounds above the upper hearing limit are termed "ultrasound", while anything below the lower hearing limit is termed "infrasound".

Echo

An echo is essentially the reflection of sound. The fraction of sound energy reflected from a surface is large if the surface is rigid and smooth. However, the fraction will be small if the surface is soft and irregular. The sound energy that is not reflected as an echo is either transmitted or absorbed.

*Note: Sound obeys the **law of reflection**. When multiple reflections of sound occur, reverberation occurs.

Definition of reverberation: Reverberation is the persistence of sound in a particular space after the original sound is removed. A reverberation occurs when a sound is produced in an enclosed space causing a large number of echoes to build up and then slowly decay as the sound is absorbed by the walls and air.

Cathode Ray Oscilloscope

The CRO plots a graph of voltage (y axis) against time (x axis).

The scales on the y and x axes can be adjusted using the time base and voltage gain controls.

Topic 5 – EM Spectrum

Definition of electromagnetic waves: Transverse waves that travel through vacuum at 3×10^8 m s^{-1}, which is the speed of light (light is an electromagnetic wave).

Types of EM Waves + Applications

EM Waves	Applications
Radio Waves	- Radio and television communication - Mobile phones - Wireless networking - Radio Astronomy
Microwaves	- Microwave Oven - Satellite television - Telephone - Astronomy - Traffic Speed Camera
Infrared waves	- Household electrical appliances - (Television) remote controllers - Intruder alarms - Night vision
Visible light	- Optical fibres - Medical uses (e.g. endoscopy) - Telecommunications

Ultraviolet light	- Sun beds - Fluorescent tubes - Sterilisation - Security Forensics
X-rays	- Hospital uses (e.g. look for fractures) - Fluorescent tubes (e.g. look for fractures) - Airport security (baggage checks) - Crystallography - Astronomy
Gamma rays	- Sterilising medical equipment - Cancer treatment - Change properties of semi-precious stones - Labelling (nuclear medicine) - Screening of ship containers

*Note: All EM waves carry energy. Therefore, any object that absorbs EM waves will either:

1. Become hotter (microwave)
2. Get ionised (produce free electrons)

If a body absorbs high-energy electromagnetic waves (e.g. UV rays, X-rays, gamma rays), the electrons may damage living cells and tissues. This effect is being used in cancer treatment.

Topic 6 – Lenses

Definition of an optical medium: A material that light can pass through, e.g. water, air, glass. An optical medium is said to be optically dense if it reduces the speed of light.

Definition of refraction: Bending of light when it passes from one medium of different optical density to another medium of a different optical density.

Converging lenses

Definition of terms

- Principal axis – the line passing through the centres of curvature of the lens
- Principal focus/focal point – A point on the principal axis where rays of light parallel to the principal axis converge. There is one on either side, which means that an ideal lens could be flipped and the results would be the same.
- Focal length – horizontal distance between focal point and optical centre of lens.
- Optical centre – imaginary point inside a lens through which a light ray is able to travel without being deviated

*Note: These lenses are thicker in the middle than on the outer edges in order for light passing through to converge, to bend towards the optical axis.

Drawing ray diagrams

A. Centre ray – Ray passing through the optical centre of the lens emerges without being deflected
B. Parallel ray – Ray parallel through the axis on the incident side passes through the focus point on the other side.
C. Focal ray – Ray through the focus point on the incident side emerges parallel on the other.

*Note: Usually A and B are sufficient to find the image location. C can serve as a check.

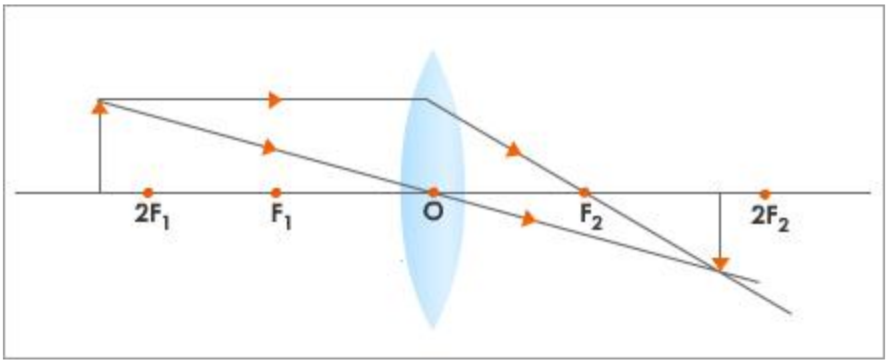
Identifying real and virtual images

Real images – Rays converge on an image point so that they could be captured on a screen

Virtual images – Rays do not converge, and so cannot be captured, but seem to come from an image point.

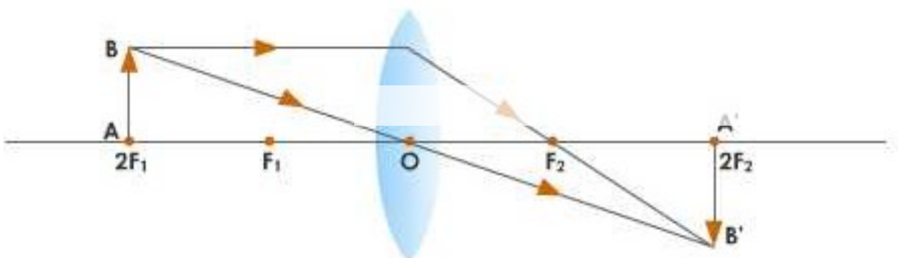
Different ray diagrams

*Note: f is focal length, u is object distance, v is image distance.



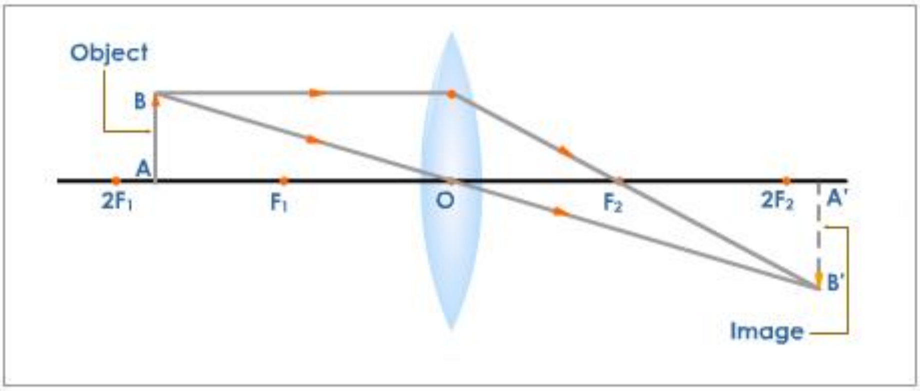
When u > 2f:

Image location: Other side
Image type: Real
Orientation: Inverted
Size: Diminished



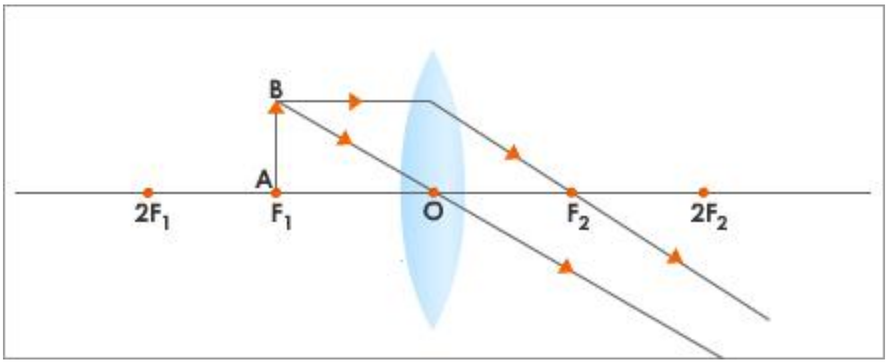
When u = 2f:

Image location: Other side
Image type: Real
Orientation: Inverted
Size: Same



When u < 2f and u > f:

Image location: Other side
Image type: Real
Orientation: Inverted
Size: Magnified



When u = f:

Image location: At infinity
Image type: Doesn't form
Orientation: Doesn't form
Size: None

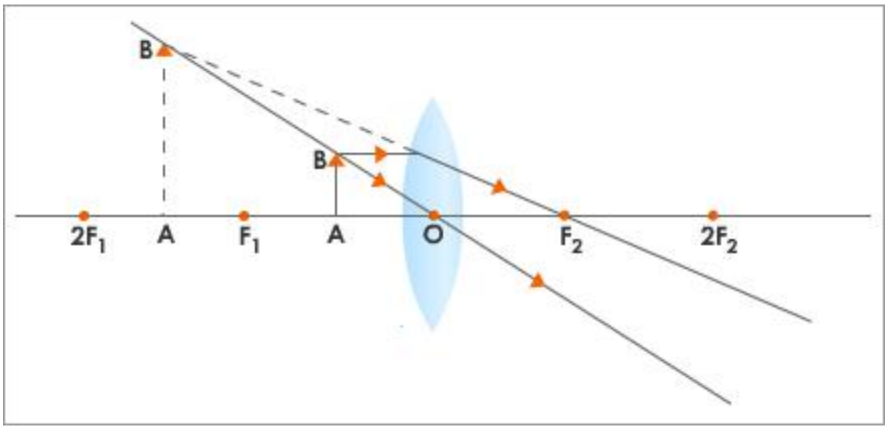


Image location: Same side

Image type: Virtual

Orientation: Upright

Size: Magnified

Formulas to remember

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ where f is focal length, u is object distance and v is image distance.

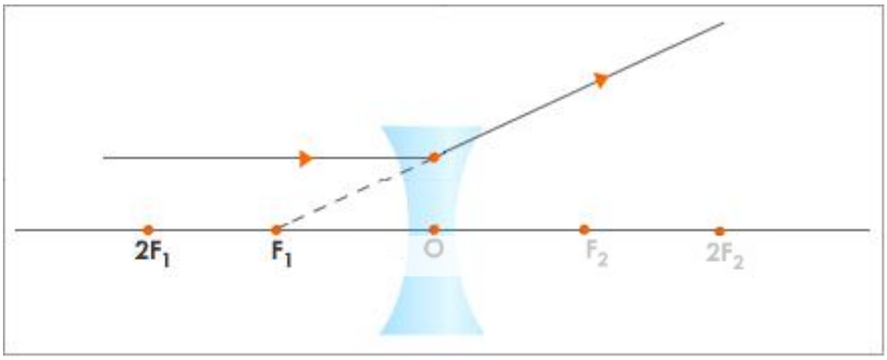
M = $\frac{v}{u}$ where M is magnification, v is image distance and u is object distance.

Diverging Lenses

Drawing diverging lenses diagrams

A. Ray passing through optical centre of lens is not deflected
B. Ray parallel to principal axis of the incident side refacts through the lens and appears to have come from the principal focus.
C. Ray heading towards the focal point emerges parallel to the principal axis.

Diverging lenses diagram



Topic 7 - Kinematics

Definition of terms

Displacement – Distance moved in a specified direction

Speed – Rate of change of distance with respect to time

Velocity – Rate of change of displacement with respect to time

Velocity

Instantaneous velocity

Definition – Rate of change of displacement at a particular instant of time.

Instantaneous velocity is given by the gradient of the tangent at a particular point of a displacement-time graph.

Formula: v = $\frac{\Delta s}{\Delta t}$

Average velocity

Definition – Total displacement divided by total time taken.

Formula: $\langle v \rangle = \frac{S}{T}$ OR $\langle v \rangle = \frac{u+v}{2}$

Acceleration

Instantaneous Acceleration

Definition – Rate of change in velocity at a particular instant of time.

Average Acceleration

Definition –Total change in velocity divided by total time taken.

Acceleration of gravity

It is always -9.81 m s^{-2} (if upwards is taken to be positive)

Air resistance

Key idea – Faster the object moves, the greater the air resistance.

Air resistance increases with:

1. Surface area (size)
2. Speed of object
3. Density of object

Terminal velocity

As an object continues to fall, the air resistance acting on the object will become non-negligible. Hence, terminal velocity is achieved when the force of air resistance is the same as the weight of the object. The object will cease to accelerate and move with a constant velocity.

Formulas to remember

1. $s = \frac{1}{2}(u + v)t$
2. $v = u + at$
3. $s = ut + \frac{1}{2}at^2$
4. $v^2 = u^2 + 2as$

*Note:
s – displacement
v – final velocity
u – initial velocity
a – acceleration
t – time taken

Topic 7 – Scalars and Vectors

Definitions

Scalars – Quantities that are fully described by magnitude alone.

Vectors – Quantities that are fully described by both a magnitude and a direction.

Addition of Vectors

Parallel vectors

If the direction of the 2 vectors is the same, then we must add one to the other.

If the vectors are in different directions, then we must subtract one from the other.

Using vector diagrams

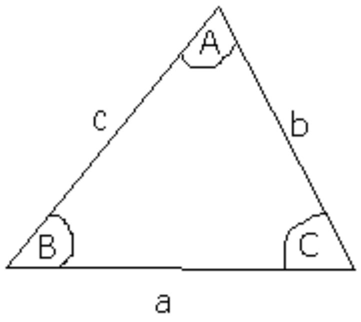
2 different methods can be used to find the resultant vector of 2 vectors at an angle to one another.

They are:

1. Vector triangle method/Head-to-tail method
2. Parallelogram method

*Refer to Physics notes and worksheets on how to address this.

Using cosine rule and sine rule



Cosine rule: $c^2 = a^2 + b^2 - 2ab\cos C$

Sine rule: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

Subtraction of vectors

Subtracting a vector can be seen as adding a negative vector.

E.g.: A – B = A + (-B)

Use the vector triangle method again to work this out.

Vector Resolution

Any vector can be resolved into its 2 components: a horizontal one and a vertical one. We can use the tangent function to find these 2 components.