Physics MYCT Notes 2013
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Class 3P

Physical Quantities, Units and Measurement Techniques:

SI Units:

- Known as the International System of Units
- Used for world synchronization (so no computing mistakes should occur as a result of using wrong units)
- Coherent system of units of measurements based around 7 base units
- Globally adopted (except for US, Burma and Liberia)
- In comparison to imperial units (which are usually not in base 10-such as ounces and feet)
- Decided upon in 1960 at the 11th General Conference on Weights and Measures (accepted by science and commerce throughout the world)

Past:

- Use of body parts for measurement (umbra: digits as length)
- Imperial unit: generally outdated and more arbitrary

Famous Errors:

- NASA mixes up imperial and metric units (causing them to waste 125 million on a launched spacecraft to Mars which missed its target)
- Apparently it costs over 350 million to convert all diagrams to metric units
- Happens in 'Murrica

Derivation of Other Quantities:

- Velocity can be computed as ms-1
- Acceleration can be computed as ms-2
- Volume is computed as m3
- Density is computed as kgm-3
- Force: kgms-2
- Work done kgm2s-2

Base Quantity	Base Unit	Symbol	Exact Definition
Length	Metre	M	The distance travelled by light in vacuum in 1/299 792 458 of a second
Mass	Kilogram	Kg	The mass of the International Prototype Kilogram
Time	Second	S	Duration of 9 192 631 770 periods of radiation corresponding the transition between the two hyperfine levels of the ground state of Caesium 133 atom
Current	Ampere	A	The constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length
Temperature	Kelvin	K	The fraction 1/273.16 of the thermodynamic temperature of the triple point of water
Amount of Substance	Mole	Mol	The amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12
Candela	Candela	cd	The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

Prefixes:

Number	**Prefix**	**Symbol**	**Number**	**Prefix**	**Symbol**

10^{1}	deka-	da	10^{-1}	deci-	d
10^{2}	hecto-	h	10^{-2}	centi-	c
10^{3}	kilo-	k	10^{-3}	milli-	m
10^{6}	mega-	M	10^{-6}	micro-	μ
10^{9}	giga-	G	10^{-9}	nano-	n
10^{12}	tera-	T	10^{-12}	pico-	p
10^{15}	peta-	P	10^{-15}	femto-	f
10^{18}	exa-	E	10^{-18}	atto-	a
10^{21}	zeta-	Z	10^{-21}	zepto-	z
10^{24}	yotta-	Y	10^{-24}	yocto-	y

SFDP:
Significant Figures: used in multiplication and division
Decimal Places: used in addition and subtraction

- Always use the value with the fewest sf/dp
- Values are always to be left in decimal places (fractions and ratios are incorrect)
- If there is a complicated equation to be solved by this method, use BODMAS and work accordingly
- For questions not related to Chapter 1 and 2, leave it in 3sf to be absolutely safe (alternatively, leave it in appropriate sf/dp)
- If question mentions the number of dp/sf, please adhere to it :D

Errors:

Random Error:

- May be due to human error (parallax or reaction time)
- Background disruption (extra noise and mechanical vibration)
- Reading can be above or below actual value (depending on uncontrolled conditions)
- Cannot be predicted or avoided
- Affects the reproducibility (precision) of the results
- Minimized by taking many readings and taking the average

Systematic Error:

- Human error or instrument being used (such as zero error or incorrect calibration)
- Environment that can be controlled (wind speed constant in one direction)
- Predictable error: all to be higher than or lower than the actual value
- Affects the accuracy of the reading
- Eliminated by subtracting or adding

Precision: Refers to how close a group of measurements are to one another
Accuracy: Refers to how close a measured value is to its true or accepted value
Alternate Definition of Accuracy: Number of decimal places (which determines how close the result is to the actual value): 2.4m vs 2.43m vs 2.435m

Comparison:

Accuracy	Precision
Requires only one reading to be determined	Requires multiple readings to be determined
Related to error	Related to uncertainty
Enhanced when systematic error is reduced	Enhanced when random error is reduced
Depends on the result (and conditions which cannot be controlled)	Depends on the instrument on being carrying out the experiment

Measurement Equipment:

Metre Ruler:

- Can only be measured to 1mm
- Markings are generally approximate and not very accurate
- Markings may fade or wood may be chipped at the ends

Vernier Caliper:
- Precision is to 0.1mm
- Used in scientific measurements
- Ability to measure length, inner diameter and depth (with the different appendages)

Zero Error:
- Positive Zero Error (leave it as +x.xx cm or +x.x mm): read from the right (the markings)
- Subtract the zero error from the reading to get the accurate answer
- Negative Zero Error (leave it as –x.xx cm or –x.x mm): read from the left (the markings)
- Add the zero error to the reading to get the accurate answer

Micrometer Screw Gauge:
- Precision is to 0.01mm
- Scientifically accurate
- Used to measure diameter or length (must be tight)

Zero Error
- Positive Zero Error (usually at +0.005cm or so): quite clear
- Subtract Zero Error from the reading
- Negative Zero Error (usually at -0.005cm, with the point at around 45-49 marking): quite clear
- Add Zero Error from the reading

<u>Waves:</u>

Definition:

- A disturbance that travels through a medium from one location to another
- Energy transport phenomenon that transports energy without transporting matter
- Particles of medium do not travel between 2 points
- **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 (determined by the **amount of energy** in the wave)
- **Period**: Time taken **to complete one oscillation** of the wave (Unit being second)
- **Frequency**: Number of oscillations made by the wave **per unit time** (Unit being Hertz)
- **Wavelength**: **Distance** between corresponding points in successive waveforms, such as the distance between 2 successive crests and troughs (usually in nanometre)
- **Speed**: Distance moved by the wave per second
- **Wavefronts**: Lines that join all the peaks and identical points on the wave
- **Peak**: highest point of a wave
- **Trough**: lowest point of a wave
- **In phase**: Set of points that have the same displacement from the point and are moving in the same direction (usually one or more wavelengths apart, in fixed integers)
- **Medium**: A physical substance made up of particles through which mechanical waves can pass through (for sound)

Notes:

- Particles in a wave oscillate around a fixed position, and does not move with the wave (proven in the cork experiment placed upon water)
- Currents in waves occur because of other forces (and not the wave itself)

Transverse Waves:

- Waves with vibrations of particles perpendicular to the direction of travel of wave motion
- Examples are EM Waves and Water Waves
- Obvious crests and trough (amplitude measured vertically)

Longitudinal Wave

- Waves with vibrations of particles parallel to the direction of travel of wave motion
- Sound waves
- Obvious compressions and rarefactions (which are measured horizontally)
- **Compression:** Particles are the closest together at this point
- **Rarefaction:** Particles are far apart at this point
- **Wavelength:** measured by compression to compression distance (where the particles are in phase)

Mechanical Waves:

- Require a medium for them to propagate
- Transfer energy through a medium

Electromagnetic Waves:

- Do not require any medium
- Ability to pass through vacuum

Formulas:

- $F=1/T$ (Frequency is inverse proportionate to Time)
- $V=F(\lambda)$ (Speed=Frequency x Wavelength)
- $V= \lambda/T$ (Speed = Wavelength/Time)

Graphical Representations:

- Displacement against Distance/Horizontal Displacement (where the distance between peaks is wavelength and the maximum displacement is the amplitude)
- Displacement against Time (where the distance between peaks is a period and the maximum displacement is the amplitude)

Experiments on Water (Refraction of Waves):

- Shallower to Deeper Region: Same Frequency, Increased Speed, Increased Wavelength
- Deeper to Shallower Region: Same Frequency, Decreased Speed, Decreased Wavelength
- Shallow Water is more dense
- Deeper Water is less dense

Experiment 2: Barriers

- Convex barrier causes the waves to focus at a particular point on the opposite side of the lens
- Concave barrier causes the waves to reflect and focus at a particular point on the same side of the lens
- Focal point of the lens is determined (to be covered under lenses)

Experiment 3: Interference

- Destructive Interference: Two waves that are symmetrical meet (cancel each other out)
- Constructive Interference: Two waves that are identical meet (and become one larger wave)
- Can be observed when two ripples are created (and destructive interference can be observed at certain points without a wave)

Experiment 4: Doppler effect

- Received frequency is higher during the approach (whereby the noise from the car becomes louder since the car is also moving relative to the observer)
- Therefore, the wavelengths become shorter (due to the movement of the car in a certain direction)
- In normal conditions, all wavelengths would be the same (due to the stationery source of noise or EM waves)
- Evident in shock waves (when planes break the sound barrier) or in normal circumstances (car sirens)

Experiment 5: Redshift

- Happens when light or other EM radiation from an object moves away from the observer
- Wavelength is increased and it appears red (which is in the 700nm zone)
- “Red” implies a lower frequency and lower photon energy
- Example of the Doppler effect
- Converse is called blueshift (where the object moves towards the observer and the wavelength is decreased)

What to remember when drawing Waves:

1. Draw the direction of the wave and take note of the distance between each wave
2. Draw the normal (either reflection or refraction)
3. Draw the line of reflection/refraction before filling up the wavefront
4. **Continuity of waves** (all waves that reach the boundary has to be continued in another direction)

Note:

- Usually a rough estimate for refracted wave (although we have our protractors on the day of the exam)

<u>Sound Waves and Cathode Ray Oscilloscope:</u>

- Form of longitudinal wave
- Particles oscillate about their equilibrium positions in a direction **parallel** to the motion of the wave
- **Vibrations** produces a series of high and low pressure regions: known as **compressions and rarefactions**
- Propagate energy from one point to another without transporting matter
- Cannot travel in vacuum (mechanical waves that require a medium)
- Sound travels faster when **particles are closer** to each other (because energy can be transferred more easily with the increased probability of collision of particles)
- Sound energy is **dissipated** as the distance increases (since the energy is lost as heat during the transfer of energy to the next particle)

Speed of sound:

- Gas: 330-350m/s
- Liquid: 1500m/s
- Solid (varies widely depending on density): 4000-5000m/s
- Cannot travel in vacuum (lack of particles to transfer energy)

What affects the speed of sound?

- Temperature: an increase in temperature increases the probability of particle collision, leading to increased wave speed (thus speed of sound increases)
- Humidity: an increase in humidity means more water molecules in the air which help to transfer energy (speed of sound increases)
- Wind (wind in the same direction, particles travel faster and transfer sound faster=increase in the speed of sound)
- Wind (wind in the opposite direction, speed of sound will decrease)

Pitch and Amplitude and Quality:

- Loudness of sound is dependent on the amplitude of the longitudinal wave (greater amplitude means an increase in volume)
- Pitch of sound depends on the frequency of the wave (greater frequency leads to a higher pitch)
- Loudness of sound is measured by decibels, in a log graph (base 10)-which means that 100 decibels is 10 times louder than 90 decibels
- Quality of a note or sound depends on its waveform (which is different based on the instrument)

Strings/Vocal Chords:

- Increased thickness of string=lower frequency
- Increased tension of string=higher frequency
- Increased length of string=lower frequency

Human Hearing:

- Can only hear from 20Hz to 20 000 Hz (blind people have a higher hearing range due to their disability, resulting in a more sensitive sense of hearing)
- Below 20Hz: humans can hear the movements of our muscles (infrasound, lower limit)
- Above 20 000Hz: ultrasound, upper limit
- Animals can have a greater hearing range than humans (like bats or elephants)

How do humans hear:

1. Pressure wave reaches the ear: series of high and low pressure regions impinge upon eardrum
2. Compression or high pressure region pushes eardrum inward (rarefaction regions pull eardrum outward)
3. Continuous arrival of high and low pressure causes eardrum to vibrate
4. Vibration sent to cochlea (amplified by middle ear bones: anvil, stirrup, hammer) where the fluids and nerve endings convert vibrations to electrical nerve impulses which are sent to brain

How to make noise:

- Vocal cords (cartilage) can be moved to generate sound
- Greater tension in the cartilage leads to a higher pitch in the voice produced
- Noise level depends on the speed of air rushing from the lungs

- Mouth/Tongue: controls air flow to shape the noises (into noises that can be discerned to mean something)

Uses of Ultrasound:

- Cleaning delicate objects (ultrasound cleaners vibrate dust particles off objects without severely damaging the object)
- Prenatal Scanning: check on the health of the fetus
- SONAR: sound navigation ranging within water (to detect obstacles and mines)

Uses of infrasound (<20Hz):

- Monitoring of earthquakes
- Charting rock and petroleum formations beneath the Earth surface
- Seismic activity (main use)

Dangers of Sound:

- Extreme high frequencies at a high energy level can burst organs (universal ban on such weapons): ability to kill millions

Echo:

- Reflection of sound (heard distinctly from the original sound)
- Echoes cannot be heard in confined spaces because the wave of echo and the original sound will merge in constructive/destructive interference (heard at the same time=reverberation)

Cathode Ray Oscilloscope:

- Oscilloscope plots a graph of voltage against time
- Scales are adjusted using time base (time per division) and voltage-gain controls (voltage per division)

EM Waves:

- Definition: **Transverse** waves that travel through vacuum at **3 x 10^8 ms-1**
- Travels at the **same speed** in all conditions
- Able to travel in vacuum
- Speed = Frequency x Wavelength (speed always ends up at 3.0 x 10^8 ms-1)

EM Wave	Frequency	Wavelength
Radio Wave	Lower than 300 MHz	Longer than 1m
Microwave	300MHz to 300 GHz	1mm to 1m
Infrared	300 GHz to 400 THz (10^12)	760nm to 1mm
Visible Light	400 to 800 THz	380nm to 760nm
Ultraviolet Light	800THz to 30 PHz (10^15)	10nm to 380nm
X-Rays	30 PHz to 30 EHz (10^18)	0.01 to 10nm
Gamma Rays	Higher than 30 EHz	Shorter than 0.01nm

Trends:

- Increase in frequency means a greater ionizing and penetrating power
- Only UV light and above (gamma/X-Rays) can ionize objects
- Frequncy is inversely proportionate to wavelength

Applications:

Radio Waves:
Sources: Electronic Devices
Detectors: Aerials of TV and radio transmittors

- Radio Communication (different channels at different wavelengths): LW, MW, SW, VHF
- TV Communication (UHF and VHF)
- Wireless networking
- Mobile phones
- Radio Astronomy

Microwaves:
Source: Electronic Devices
Detectors: Valve circuit arrange as microwave receivers
Effect: make objects warmer
Effect: rotate water molecules to generate thermal energy rapidly (spinning plate in microwaves)
Note: Can travel in a straight line without losing its energy

- Microwave Oven (10cm wavelength)
- Television
- Telephone
- Satellite Television
- Traffic Speed Camera

Infrared:
Sources: Warm bodies or the Sun
Detectors: Blackened thermometers, thermocouples, special photographic film
Effect: Heat (all objects with a temperature above 0 Kelvin will emit infra-red waves, even an ice cube)
Note: Warm objects emit more infrared rays compared to cool objects

- Household electrical appliances
- Television remote controllers
- Intruder alarms
- Night Vision
- Optical fibres (able to go around bends)

Visible Light:
Source: Hot Bodies, Laser and the Sun
Detectors: Eyes, photographic film and photographic cells

- Optical Fibres

- Medical uses
- Telecommunications
- Chemical spectrum analysis

Ultraviolet:
Source: Mercury vapour, lamps and the Sun
Detectors: Dyes and photocells
Effects: Stimulates human bodies to produce vitamin D

- Sun-beds
- Fluorescent Tubes
- Sterilization (killing of microbes at 280nm)
- Forensics
- Detection of Counterfeit Money

X-Rays:
Source: X-Ray tubes
Detectors: Photographic film and fluorescent screens
Effects: penetrating to damage tissues in organisms

- Hospital use
- Engineering applications
- Fluorescent Tubes (identification of fractures)
- X-Ray Crystallography (identify substances)
- Astronomy

Gamma Rays:
Source: cosmic rays, radioactive substances and nuclear reaction (fission or fusion)
Detectors: Geiger-Muller counters, photographic film and bubble/cloud chambers

- Medical treatment (kill cancer cells): gamma knife surgery
- Checking of cracks in pipes
- Sterilizing medical equipment
- Change properties of semi-precious stones
- Check contents of boxes and items in ship containers
- Screening of ship containers

Detriments:
UV light:

- Lead to cataract and skin cancer
- Microwave ovens are designed to cook meat with waves from all directions (if the meat is not too large, amount of radiation reaching centre of meat from all directions is greater than that on any one side – centre is cooked first)

Notes:

- UV rays can penetrate through clouds, but are absorbed by glass (greenhouses or spectacle lenses)

Lenses (Chapter 6):

Refraction of light:

- Angle of incidence and angle of refraction (from Sec 2)
- Occurs because light travels at different speeds in different mediums
- Less dense to dense=bend towards the normal
- Critical angle and total internal reflection (from Sec 2)
- Snell's Law: $n_1 \sin i = n_2 \sin r$

Definition of Terms:

- Optical Medium: material that light can pass through (water, air, glass): optical medium is dense if it reduces the speed of light
- Refraction: Bending of light when it passes from one medium of different optical density to another medium of a different optical density
- Principal Axis: Line passing through the centres of curvature of the lens (no refraction)
- Principal focus or focal point: a point on the principal axis where rays of light parallel to the principal axis converge
- Focal length: horizontal distance between the principal focus and the optical centre of the lens
- Optical centre: imaginary point inside a lens through which a light ray is able to travel without being deviated
- Linear magnification factor: ratio of the **image size to the object size** (can be also obtained from the ratio of the **image distance** from the optical centre to the **object distance** from the optical centre)

CONVERGING LENSES:

- Convex lenses are thicker in the middle than on the outer edges
- Causes light to refract towards a point on the other side of the lens (opposite from where the light rays are shining)

Object Distance	Image Distance (resultant)	Description of Image	Application
Image further than 2F	F<V<2F	Real, inverted at diminished	-Camera (photographic film)
2F	2F	Real, inverted and of the same size	-Exact-size photocopier -Inverting lens of a field telescope
F<U<2F	Image further than 2F	Real, inverted and magnified	-Projector -Objective lens of Microscope
F	At infinity	No image created	-Spotlight -Lenses used in lighthouses and searchlights
<F	Same side as object (negative image distance)	Virtual, upright, magnified	-Magnifying Glass -Eyepiece of Microscope -Binoculars and Telescope

Drawing ray diagrams:

1. Centre Ray- Ray passing through the optical centre and emerges without being deflected
2. Parallel Ray- parallel to the axis on the incident side, passes through focal point on the other side
3. Focal ray: passes through focal point on incident side and emerges parallel on the other
4. Rays should converge at a point (make sure ray arrows are drawn and the object is labeled)

Myopia:

- Near-sighted (whereby objects far away appear blur)
- Abnormally long eyeball or a strong lens
- Light bends too much at the lens (therefore image is created at the wrong location)
- Focal point of the light rays closer to the lens compared to the retina
- Sharper vision underwater (since the light rays bend less towards the retina)
- Corrected by concave glasses: that allow light to diverge before converging again

Hyperopia:

- Long-sighted (whereby objects near appear blur)

- Eye lens becomes too weak (or an abnormally short eyeball)
- Light bends too little at the lens (image is formed behind the retina and is not focused at the correct position)
- Worse vision underwater (since the light rays bend even less towards the retina)
- Corrected by convex glasses that converge light rays before reaching the lens)

Formula:

- 1/u + 1/v = 1/f (for images that are real and inverted)
    - f is positive for converging lenses, and negative for diverging lenses
    - u is positive if object is on the side of the lens from which the light is coming
    - v is positive if the image is on the opposite side of the lens (same side of lens=negative v distance)
- 1/f = 1/u – 1/v (for images that are virtual)
- M = Hi/Ho (height of image divided by height of object)
- M= v/u (magnification=image distance divided by object distance)
    - If image is larger than object, magnification factor is >1
    - If image is smaller than object, magnification factor is <1

DIVERGING LENSES

- Concave lenses, where the lens is thinner in the middle than on the outer edges
- Light passing through will diverge and bend away from principal axis
- By retracing the light path (that is refracted) it will always end up on the principal focal point (on the side of the light ray)

Human Eye

- Retina is the light-sensitive screen at the rear of the eye
- Cornea and lens refract light towards a point on the retina
- Iris controls the amount of light entering the eye
- Power of accommodation is the eye's ability to focus a real image of an object on the retina

Kinematics (Chapter 7):

Definition:

- Distance: total length covered by a moving object irrespective of the direction of the motion
- 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
- Instantaneous velocity: rate of change of displacement at a particular instant of time (change s/change t)
- Average velocity: Total displacement divided by total time taken (u+v / 2)
- Instantaneous Acceleration: Rate of change in velocity at a particular instant of time
- Average acceleration: Total change in velocity divided by the total time taken
- Acceleration of Gravity: it is always 9.81 ms-2

Gradient and Graph:

- Gradient of the displacement-time graph: velocity of object
- Gradient of velocity-time graph gives acceleration (area is under the graph gives displacement)
- Deceleration = slowing down or decreasing acceleration (getting faster at a slower rate)
- Retardation: can never be negative
- Acceleration-time graph (shows the rate of acceleration)

Formulas:

- $V^2 = u^2 + 2as$
- $S=ut + \frac{1}{2} at^2$
- $V= u + at$
- $S= \frac{1}{2} (u+v) t$
- $S= vt - \frac{1}{2} at^2$

Air Resistance:

- Increases with surface area
- Increases with the speed of the object
- Increases with the density of the object

Terminal Velocity:

- Achieved when the force of the air resistance is the same as the weight of the object
- Object will cease to accelerate and move with constant velocity
- Longer time taken for heavier objects to reach terminal velocity
- Longer time taken for objects with less surface area
- Longer time taken for objects that are denser

Note:

- Speed should never be mixed up with velocity (one has a direction and can be negative: relative to the starting point)

Vectors and Scalars (Chapter 8):

Definitions:

- Scalar: described by magnitude alone
- Scalar (eg.): distance, speed, time, mass, area, volume, energy, power
- Vector: described by both a magnitude and a direction
- Vector (eg.): displacement, velocity, acceleration, force, momentum

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

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