Mid Year Common Test Notes: Physics

Sources: Textbook, Lesson Notes, Lesson Slides, Worksheets, Notes (Harish)

Topic 1 and 2: Physical Quantities, Units, Measurement Techniques

Accuracy and Precision

Accuracy: The ability of a measurement to match the actual value of the quantity being measured.

Precision: The ability of a measurement to be consistently reproduced.

Accuracy	Precision
Requires only a single measurement to verify.	Requires multiple measurements to verify.
Requires true value to verify	Does not require true value to verify
Is affected by systematic errors	Is affected by random errors
Refers to how close the measured value is to the true or accepted value.	Refers to how close a group of measurements are to one another.

Errors

Random Errors:

- Occur in all measurements unpredictably.
- Causes readings to scatter to both sides of the true or accepted value
- When readings are averaged out, the mean is usually close to the true or accepted value
- Affects the precision of the readings
- Cannot be avoided (no constant source of error).
- Examples: Reaction time, background noise.

Systematic Errors:

- Occurs due to bad calibration, bad observation techniques, environmental factors
- Causes readings to deviate to only one side of the true value (either higher or lower)
- When averaged out, the mean of the reading will deviate significantly from the true value
- Affects the accuracy of the readings
- Can be avoided of the source of the error is found.
- Examples: Incorrect calibration

*Parallax error can be both random and systematic (depending on the cause). Do not use parallax error as an answer for random/systematic errors.

Measurement

Intervals: Intervals are when you need to take multiple measurements to compare them with one another. For example, ruler (where we set the start of the line at 0cm and final reading = final reading – 0cm)

- A measurement is recorded to half the smallest division of the smallest scale of the instrument if measurements do not involve intervals (eg. reading off a thermometer).
- A measurement is recorded to the smallest division if the measurements involve intervals (eg. Measuring angle with protractor)

SI Units

Base Quantity	Base Unit	Symbol
Length	metre	m
Mass	Kilogram	kg
Time	Second	s
Current	Ampere	A
Temperature	kelvin	K
Amount (Substance)	mole	mol
Luminous Intensity	candela	cd

* Everything is measurable by these base SI units, or units derived from these bases.

Prefixes

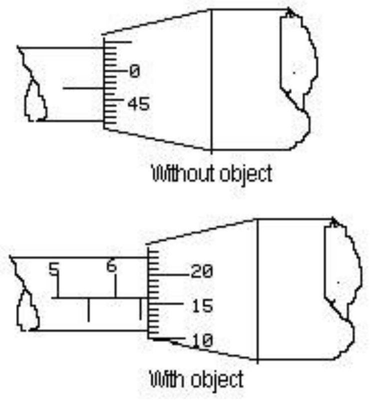
deca	da	1×10^{1}
hector	h	1×10^{2}
kilo	k	1×10^{3}
mega	M	1×10^{6}
giga	G	1×10^{9}
tera	T	1×10^{12}
peta	P	1×10^{15}
exa	E	1×10^{18}

deci	d	1×10^{-1}
centi	c	1×10^{-2}
milli	m	1×10^{-3}
micro	u	1×10^{-6}
nano	n	1×10^{-9}
pico	p	1×10^{-12}
femto	f	1×10^{-15}
atto	a	1×10^{-18}

Measurements: Vernier Calipers and Micrometer Screw Gauge

- When you have a negative zero error on the vernier calipers (reading is negative, less than zero), you read the value on the vernier scale backwards from 10.
- The micrometer roll is pushed downwards towards you (toilet roll style).

- The zero error is -0.2mm (as the 0.8mm line is subtracted from 1.0mm)



- The zero error is 0.03mm (count backwards).
- Vernier calipers – x.xx cm
- Micrometer screw gauge – x.xx mm
- For ticker-timers, count the number of intervals, not the number of dots (if 10 dots: 9 intervals, if 3 dots: 2 intervals

SF and DP Rules, Calculations

* Use SF and DP rules mainly in questions regarding topic 1 and 2. For the rest of the topics, 3sf should be a safe bet.

SF and DP Rule: Round off the answer to the least precise measurement used in the calculation.

- Only apply these rules in the final step.
- Do not consider the sf/dp of constants.
- If the calculation has addition and subtraction, use the DP rule (lowest number of DP).
- If the calculation has multiplication and division, use the SF rule (lowest number of SF).

Ratio should always be expressed as a decimal number to 3sf. (Express ¾ as 0.750).

Topic 3: Waves

Definitions

Wave: A wave is a disturbance in space that transfers energy away from its source (note that the particles in the wave do not move together with the wave but vibrate along their own axes, and while energy is transferred, matter is not).

- Transverse waves: Waves that travel perpendicular to the direction of particle vibration (such as an EM wave)
- Longitudinal waves: Waves that travel parallel to the direction of particle vibration (such as a sound wave)
    - The compressions and rarefactions of longitudinal waves will slide in the direction of propagation.

Transverse Waves	Longitudinal Waves
Direction of propagation is perpendicular to the direction of vibrations.	Direction of propagation is parallel to the direction of vibrations.
Positions of maximum and minimum displacement are called crests and troughs.	Positions of maximum and minimum displacement are called compressions and rarefactions.

Some transverse waves can propagate without a medium (example: EM Waves).	All longitudinal waves require a medium to propagate (example: Sound Waves).

- Displacement: The distance of the oscillating particle in a wave from its original equilibrium position at any instant
- Amplitude: The maximum displacement of the oscillating particle in a wave from the equilibrium position
- Crests and troughs: Points of highest and lowest displacement from equilibrium (respectively) on a transverse wave
- Compressions and rarefactions: Points of highest and lowest displacement from equilibrium (respectively) on a longitudinal wave
- Phase: Any two points moving in the same direction and having the same speed and displacement from the rest position (equilibrium) are said to be in phase.
- Wavelength: Shortest distance between any two points that are in phase (such as two successive crests or troughs)
  - Symbol: Lambda (λ)
- Equilibrium: Maximum displacement from rest or centre position (height of crest or depth of trough from equilibrium)
- Frequency (f): The number of crests or troughs that pass a certain point per second (in other words, the number of complete waves generated per second)
  - Symbol: Hertz (Hz)
- Period (T): The time (in seconds) it takes to generate one complete wave. Also the time taken for one wave to move the distance of one wavelength
- Speed (v): Distance moved by the wave per second.
  - Frequency x Wavelength
- Wavefront: An imaginary line on a wave that joins all points which are in the same phase.
  - Distance between wavefronts is the wavelength
  - Can be circular in circular waves.

Important Equations:

- Frequency and Period can be derived from one another:
  - T= 1/f
- Speed can be determined by both frequency and period with the wavelength:
  - V=F x Wavelength
  - V=Wavelength/Period

Graphical Representation

- A displacement-distance graph shows the positions of all the particles in a wave at one particular instant of time.
  - Can obtain wavelength and amplitude
- A displacement-time graph shows the positions of only one particle in a wave over time.
  - Can obtain period and frequency
- To find out if a single point has moved up or down after certain time, draw the same wave at a slightly later point, and see whether the new wave is above or below the particular point

now. If it is below, the point has moved downwards and vice versa. (Explanation: While the waves moves, the point only moves up or down, so draw a Y axis on the point, and look at whether the point on the same vertical plane on the new graph is above or below the original wave).

* Both transverse and longitudinal waves will produce the same displacement-distance graph, just that the displacement for transverse waves is above and below the equilibrium, whereas the displacement for longitudinal waves is left and right of the equilibrium.

Water Waves

- Plane waves are generated by splashing a rod up and down, while circular waves are generated by splashing a circular ball up and down.
- Changing depths of water:
  - The shallower the water, the shorter the wavelength of the wave, and the deeper the water, the longer the wavelength of the wave
  - The frequency of the wave remains unchanged (because this is controlled by how often the rod/ball is dipped into the water).
  - Thus, water is faster in deeper water, and slower in shallower water.
  - Refraction:
    - If water speed changes from **faster → slower**, refraction **towards** normal
    - If water speed changes from **slower → faster**, refraction **away from** normal
    - Can use car-tyre analogy.
- Drawing (Refraction):
  - Draw the direction of the wave (perpendicular to the wavefronts). This is also the angle of incidence.
  - Draw normal
  - Draw the direction of wave refraction, also the angle of refraction (and determine wavelength if necessary).
    - Calculate using Snell's Law
  - Draw the refracted wavefronts.
- Drawing (Reflection):
  - Draw the direction of the wave (perpendicular to the wavefronts). Also the angle of incidence.
  - Draw normal
  - Draw the direction of the reflected waves, also the angle of reflection (wavelength should be the same if depth of water is not changed).
    - Calculate: angle of incidence (from normal) = angle of reflection (from normal)
  - Draw the reflected wavefronts.

Topic 4: Sound and CRO

- Sound waves are longitudinal (comprising of compressions and rarefactions), and they propagate from one point to another without transporting matter.
- Sound needs a vibrating source, as well as a medium.

    - Note: Sound waves cannot be transmitted without a medium.
- When the tuning fork is struck, the prongs repeatedly move in and out – resulting in the pushing and pulling of the surrounding air layers. This results in compressions and rarefactions, which in turn push our eardrum in and out, allowing us to sense the sound.
    - Essentially, the immediate particles vibrate, which then collide with subsequent surrounding particles which then vibrate, and the disturbance is passed on.
- Along a sound wave, there are pressure variations:
    - Regions of compressions have higher pressure (more matter compressed into unit space)
    - Regions of rarefactions have lower pressure (less matter in unit space)
    - Regions of higher pressure push the eardrum inwards, while regions of lower pressure push eardrum outwards.
        - The eardrum this vibrates, and these vibrations are transmitted to the fluid of the inner ear where they are converted to electrical pulses to be sent to the brain via the nerves.
- The speed of sound (in air) is around $300ms^{-1}$ but it can change, because the speed of sound depends on the **probability of particle collision**:
    - Sound propagates faster in denser media.
    - Sound travels fastest through solids, and slowest through gas (due to how closely packed together the particles are)
    - The higher the temperature of an object is, the faster the vibrations of the particles in it, thus allowing sound to travel faster. Thus, the higher the temperature of an object is, the faster the speed of sound.
    - The higher the humidity, the closer together particles in the atmosphere are packed together (due to the increased amount of water vapour concentration). Thus, the higher the humidity, the faster the speed of sound.
    - Wind speed affects the speed of sound too:
        - If the wind is travelling in the same direction as the propagation of sound, speed of sound will be faster than in the scenario with no wind.
        - If the wind is travelling in a direction opposite to the propagation of sound, speed of sound will be slower than in the scenario with no wind.
        - Wind speed can be calculated by solving simultaneously two equations, with different directions of wind and their respective speeds.
- The loudness of sound depends on the amplitude of the sound wave.
    - Larger amplitude contains more energy and is thus louder in volume.
- The pitch of sound depends on the frequency of the sound wave.
    - Sound waves of higher frequency produce a higher pitch note.
    - Higher pitch sounds are produced on drums with smaller surfaces, and flutes with less holes covered (because length of vibrating column becomes shorter). Vice versa applies.
- Audible frequencies for the average human ear are between 20Hz and 20kHz. This range decreases as we get older as our ears lose their sensitivity to the extreme ends of the frequency range.
    - Sounds above this frequency limit are known as ultrasound ($f>20kHz$)

- Applications: Ultrasonic cleaners (use ultrasound to clean delicate items), prenatal scans, SONAR (navigation, weather forecasting, tracking of aircrafts, missiles, etc)
    - Sounds below this frequency limit are known as infrasound ($f<20Hz$)
- Echoes are the reflections of sound.
    - The fractions of the original sound energy (volume) reflected is larger if the surface of reflection is rigid and smooth, and smaller if the surface is small and irregular.
    - All sound energy that is not reflected is transmitted or absorbed.
    - Reverberation is the persistence of sound in a particular space (due to reflections) after the original sound is removed, and is created when a sound is produced in an enclosed space causing a large number of echoes to build up and slowly decay as the sound is absorbed by the walls and the air.
    - The same not played on the piano and the violin sound different (even if they are of the same pitch and loudness), because there is a difference in the quality (or timbre) of the note. The quality of a note depends on it's waveform.
- Cathode Ray Oscilloscope: Plots a graph of voltage (y axis) against time (x axis).
    - Generally a displacement time graph of the sound wave.
    - The voltage-base controls (voltage per division) can be adjusted to control the scale of the Y Axis.
    - The time-base controls (time per division) can be adjusted to control the scale of the X Axis.

Topic 5: EM Spectrum

Electromagnetic waves are transverse waves which transfer energy from one place to another. They follow all wave properties (such as reflection), and travel through a vacuum at the speed of light. All EM waves obey the wave equation (speed = frequency x wavelength).

- EM Waves (from longest wavelength to shortest): Radio wave, microwave, infrared, visible light (ROYGBIV), ultraviolet, x rays, gamma rays.
    - Shortest wavelength has highest frequency, and longest wavelength has lowest frequency (to maintain the same speed of light).
- Radio waves have the shortest wavelength and the highest frequency in the EM spectrum

Wave	Description	Sources	Detectors	Applications
Radio Waves	Longest wave in the EM spectrum, with a wavelength of 10^{-1} to 10^{5} m, and frequencies lower than 300megahertz.	Electronic Devices	Aerials of TV and radio transmitters	Radio Astronomy, Radar Communications, Mobile phones, Wireless Networking

Wave	Description	Sources	Detectors	Applications
Microwave	Wavelengths between 1mm and 1m and frequencies between 300	Electronic Devices	Microwave receiver	Microwave ovens, satellite television, telephone, traffic speed camera.

	megahertz and 300 gigahertz			

Wave	Description	Sources	Detectors	Applications
Infrared waves	Wavelengths between 760nm and 1mm, and frequencies between 300 gigahertz and 400 terahertz	All warm bodies, such as the sun.	Blackened thermometers, special photographic film	Household electrical appliances (TV remotes), intruder alarms, night vision

Wave	Description	Sources	Detectors	Applications
Visible Light	Wavelengths between 380 nm and 760 nm, and frequencies between 400 and 800 terahertz, and can be seen by the human eye	Sun, hot bodies, lasers, fires, etc	Human eyes, photographic film, photocells	Optical fibres, telecommunications, photography, etc

Wave	Description	Sources	Detectors	Applications
Ultraviolet	Stimulates our bodies to produce vitamin C. Wavelengths between 10 and 380 nm, and frequencies between 800 terahertz and 30 petahertz	Lamps, sun, mercury vapour	Dyes, photocells	Sun beds, fluorescent tubes, sterilisation, security, forensics

Wave	Description	Sources	Detectors	Applications
X Rays	Wavelengths between 0.01 and 10nm, and frequencies between 30 petahertz and 30 exahertz	X Ray tubes	Photographic film, fluorescent screens	Medical/dental inspections, analysis of crystal structures, checking of welds

Wave	Description	Sources	Detectors	Applications
Gamma rays	Wavelengths shorter than 0.01nm and frequencies higher than 30 exahertz	Cosmic rays, radioactive substances,	Geiger-Muller counters, bubble/cloud chambers,	Sterilizing medical equipment, cancer treatment, screening of ship containers.

		nuclear reactions	photographic film	

- Ionizing radiation: Forms of radiation with enough energy to ionize molecules and atoms
    - Gamma rays, X Rays, and some UV rays are ionizing
- Non-ionizing radiation: Forms of radiation which do not carry enough energy to ionize molecules and atoms.
    - UV rays, visible light, infrared, microwaves, and radio waves are non-ionizing.
    - Non-ionizing waves have only enough energy to excite molecules, but not enough to ionize them.

Topic 6: Lenses

Refer to notes made for Quiz 2.

Topic 7: Kinematics

Refer to notes made for Quiz 2.

Topic 8: Scalars and Vectors

Objectives:

- Distinguish between scalars and vectors and give examples of each.
- Draw scale diagrams to add and subtract (two or more) coplanar vectors.
- Resolve vectors into their perpendicular components and add or subtract these components.
- Understand that projectile motion is the result of two velocity vectors (one constant and one variable).

Definitions, Examples

Scalars: Quantities that are fully described by a magnitude alone (eg. Distance speed, time, mass, area, volume, energy, power).

Vectors: Quantities that are fully described by both a magnitude and a direction (eg. Displacement, velocity, acceleration, force, momentum).

Vector Addition

[Only applicable when both vectors **have the same direction**]

When the vectors have the same direction, add the magnitudes of the two vectors up.

Vector Subtraction

[Only applicable when both vectors have opposite directions (180^{o} to one another)]

When the vectors have opposite directions, subtract the magnitudes of the two vectors.

Vector Addition/Subtraction (Vector Diagrams)

[Applicable to when the vectors are at any angle to one another]

1. Choose an appropriate scale.
2. Draw vector 1 as an arrow in the appropriate direction, with the appropriate length (magnitude).
3. Draw vector 2, ensuring that the tail of one vector is touching the head of another.
4. Draw a third arrow (resultant vector):
    a. The head of the resultant vector is at the empty head.
    b. The tail of the resultant vector is at the empty tail.
5. Calculate angle/length (direction/magnitude) using trigonometry, or measure the diagram (which is drawn to scale).

Alternatively use the parallelogram method: Connect the original vector components tail-tail, and complete the parallelogram using dotted lines. The resultant vector is the diagonal of the parallelogram, with its tail connected to the other two tails.

Vector Resolution

Is essentially, doing the reverse of vector addition/subtraction – deriving the horizontal and vertical components of the given vector.

Use basic trigonometry (secondary 2) to derive horizontal and vertical components.

Projectile Motion

*Assume that air resistance and friction are negligible.

- Projectile motion can be resolved into a horizontal and vertical component.
    - The vertical component is a variable.
    - The horizontal component is a constant (because air resistance and friction are negligible).
- The direction of the velocity of the projectile is the angle of the line (or tangent if it is a curve).

SPA Skills

Data

- For a straight line graph, minimum 6 sets of readings are required. For a curve, at least 8 to 10 sets of readings.
- Repeat readings to ensure accuracy.
- Raw data should be given to the same degree of precision to which the apparatus used is.
    - Thus for raw data, all readings in the same column must have the same number of decimal places.
- All data should be presented in the same table.
    - Every column should have a heading consisting of the (quantity/unit).
    - Conventional abbreviations (such as *t* for time) may be used.

- For processed data (data calculated by using the raw data), use the SF and DP rules.
  - For average, use the DP rule (because they must be added before averaging out the values).
- Range of values:
  - Must be taken as wide as experimental set up allows (and cover the entire range). For example, if the given range is 0.5m and 1m, and 3 readings must be taken, then (0.5m, 0.75m, and 1.0m)
  - Must be spaced out evenly across the range.

Proportion

- Linear Proportionality: When a increases, b increases
- Direct Proportionality: When a=0: b=0, when a=1: b=a, or when c=3: b=30, when c=4: b=40. In other words, gradient of graph does not change across the graph.

Graph

- Use pencil for graph (but table of values in pen)!
- Label both axes – (Quantity/Unit). Example: (Temperature/^{o}C)
- Label graph: Y against A. Example: (Resistance of a copper wire against temperature)
- Draw the X and Y axis on the major grid lines (the thick ones).
  - Label the axes on the major grid lines too.
  - Axes need not start from zero (and if they do not, do not use the zig-zag symbol to indicate the false origin).
- Scale
  - Must occupy more than half the page in both directions
  - Must be 1:1, 1:2 or 1:5
- Line of best fit:
  - As many points lie on the line as possible.
  - Equal number of points deviated on either side of line (equal space too)