Spec reference	Spec point	Additional guidance
Kinematics 3.1.1	Displacement, instantaneous speed, average speed, velocity and acceleration. Graphical representation: Displacement-time Velocity-time Acceleration time.	Define terms. Gradient = velocity Gradient = acceleration; area under graph = displacement.
Linear motion 3.1.2	Equations of motion for constant acceleration in a straight-line including motion of bodies in a uniform gravitational field without air resistance (***suvats***) Techniques and procedures used to investigate the motion and collisions of objects. Acceleration of free fall (PAG 1.1) Techniques and procedures used to determine g using trap door method or light gates.	$s = ut + \frac{1}{2}at^2$ $v = u + at$ $v^2=u^2 +2as$ $s = \frac{1}{2} (u + v)t$ Possible derivation of the equations from a graph. Light gates, data loggers, ticker tape, air track, video techniques. Evaluation: Introduction to graphical methods of determining constants (e.g. ***g***). Determining percentage error in value. Uncertainty using line of worst best fit. Describing limitations.
Projectile motion 3.1.3	Independence of the horizontal and vertical components of velocity. Resolving a vector into two perpendicular components; $F_x = F \cos\Theta$ $F_y = F \sin \Theta$.	 Introduction of the concept of resolution of vectors into components in the context of projectile motion. $v_V = v\sin \Theta$. $v_H = v\cos\Theta$

	Two-dimensional motion of a projectile with constant velocity in one direction (i.e. horizontal and constant acceleration in the perpendicular direction.	Comparison of velocity/time and displacement/time graphs representing each component's motion.
3.2.1 Dynamics	a) Net/resultant force = mass × acceleration; **F = ma** b) the newton as the unit of force c) weight of an object; **W = mg** d) the terms tension, normal contact force, upthrust and friction. e) free-body diagrams f) one- and two-dimensional motion under constant force.	Recall this equation! Force required for a mass of 1kg to accelerate at $1ms^{-2}$ Recall this equation also. Construct and interpret. Vector triangles to calculate resultant force.
3.2.2 Motion with non-uniform acceleration	Drag as the frictional force experienced by an object travelling through a fluid Factors affecting drag for an object travelling through air Motion of objects falling in a uniform gravitational field in the presence of drag i. terminal velocity ii. techniques and procedures used to determine terminal velocity in fluids.	Laminar flow only. Speed, Area, viscosity of fluid (PAG). Might be useful to know that $D = kAv^2$ where A = cross-sectional area in contact with the fluid, v = speed relative to the fluid and k is a constant dependent on the physical nature of the fluid. Description and explanation of how the forces acting change during motion and how this affects the motion, resulting in terminal velocity. Stokes' law

3.2.3 Equilibrium	a) moment of force b) couple; torque of a couple c) the principle of moments d) centre of mass; centre of gravity; experimental determination of centre of gravity e) equilibrium of an object under the action of forces and torques f) condition for equilibrium of three coplanar forces; triangle of forces.	Force x perpendicular distance from the pivot to the line of action of the force. Torque - a pair of forces in translational equilibrium, but not in rotational equilibrium. Net moment = one of the forces x their distance apart. Condition for rotational equilibrium: the sum of the anticlockwise moments = the sum of the anticlockwise moments **<u>about a point/pivot</u>**. **<u>Point</u>** on an object where its mass appears to be concentrated. Comparison of systems in translational equilibrium (sum of forces = 0) and rotational equilibrium (sum of moments =0). Drawing from scale or applying the idea of triangles (SOHCATOA, sine or cosine rule). NB/ These problems can also be solved by resolving forces/ taking components.

3.2.4 Density and pressure	a) Density; ρ =M/V; b) Pressure; p =F/A; unit Pascal (Pa) c) p = ρgh; upthrust on an object in a fluid; Archimedes' principle.	Standard calculations. Density of a spherical ball, including calculation of uncertainties. Pressure due to the column of water above a point immersed in a fluid. "***The upthrust experienced by an object either partially or wholly immersed in a fluid is equal to the weight of the fluid displaced***." Analysis of free-body diagrams involving bodies falling through a fluid (weight, drag and upthrust) and the motion thereof. **PAG = Stokes' Law**
3.3.1 Work and conservation of energy	a) Work done by a force; the unit joule b) *W = Fx cosΘ* for work done by a force. c) The principle of the conservation of energy d) energy in different forms. Energy transfers and conservation. e) energy transferred = work done.	Work done = Force x distance moved in the direction of the force. Force x component of displacement in the direction of the force. Elastic (strain), chemical, KE, GPE, etc.

3.3.2 Kinetic and potential energies	a) KE of an object EKE = ½ mv^2 b) GPE of an object in a uniform gravitational field. EGPE = mgh c) The exchange between GPE and KE.	Derivation from $v^2 = u^2 + 2as$ (first principles). Derivation from first principles. The Earth's gravitational field is considered to be uniform close to its surface.
3.3.3 Power	a) Power: P = W/t; the unit the Watt. b) P =Fv c) Efficiency of a mechanical system: $\text{efficiency} = \frac{\textit{useful output energy}}{\textit{total input energy}} \times 100\%$	Derivation of this equation from first principles is expected (P = W/t = (F x d)/t ; d/t = v)
3.4.1 Springs	a) tensile and compressive deformation; extension and compression b) Hooke's law c) force constant k of a spring or wire; F = k*x* d) (i) force–extension (or compression) graphs for springs and wires (ii) techniques and procedures used to investigate force–extension characteristics for arrangements which may include springs, rubber bands, polythene strips.	Meaning of each. Load Force α extension Useful comparison to m = F/a and R =V/I Gradient of Force against extension graph = k PAG – Springs in series and in parallel, leading to a derivation of Young's Modulus.
3.4.2 Mechanical properties of matter	(a) force–extension (or compression) graph; work done is area under graph	Hysteresis loops – heat loss in loading/unloading. Area = **<u>average</u>** force x extension

	(b) elastic potential energy; E = Fx; E = kx^2 (c) stress, strain and ultimate tensile strength (d) (i) Young modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$, $E = \frac{\sigma}{\varepsilon}$ (ii) techniques and procedures used to determine the Young modulus for a metal (e) stress–strain graphs for typical ductile, brittle and polymeric materials (f) elastic and plastic deformations of materials.	Proportionality relationships: EPE α x^2 Stress causes strain. Units of Stress (Pa), strain is unitless. Unit = Pa, and is a constant for a given material that obeys Hooke's law (metal wires). Use of equipment: micrometer, metre rule, Newtonmeter, need for long wires. Calculation using gradient of Force/extension or Stress/Strain graph. Identify graph and describe the behaviour. Breaking stress for a given material = a constant. Elastic behaviour as material returns to original length after load removed, whereas with plastic deformation, it is permanently deformed.
3.5.1 Newton's laws of motion	(a) Newton's three laws of motion (b) linear momentum; p = mv; vector nature of momentum (c) net force = rate of change of momentum; $F = \frac{\Delta p}{\Delta t}$	Newton's Third law, to include that the **nature** of the forces is the same, e.g., gravitational or electromagnetic. A scalar x a vector = a vector. Units: $kgms^{-1}$ or Ns Understanding that F =ma is a special case useable if the mass remains constant.

	(d) impulse of a force; impulse = $F\Delta t$ (e) impulse is equal to the area under a force –time graph.	Spreadsheet methods of calculating impulse by iteration Estimation of impulse from area under graph in non-linear Force against time graphs using counting of squares method.
3.5.2 Collisions	(a) the principle of conservation of momentum (b) collisions and interaction of bodies in one dimension and in two dimensions (c) perfectly elastic collision and inelastic collision.	For a closed system, the **total** momentum before an event = the **total** momentum after the event. A closed system is a group of objects that interact where no external forces act and no energy is lost. Collisions may involve objects sticking together or bouncing off each other. For explosions, the total momentum before = total momentum after = 0. Link to Newton's 2nd and 3rd law involving impulse and momentum conservation. 2-D calculations involve the use of horizontal and vertical components of momentum that remain constant in all directions before and after an event. Elastic – the total ***Kinetic energy*** before an event = the total kinetic energy after the event.