THE ACADEMY OF ST NICHOLAS	Y13 Applied	CH07 7.1,7.2,7.3,7.4	Mechanics Equilibrium and Statics	Lessons 4

Essential Knowledge Milestones

- understand that a body is in equilibrium under a set of concurrent (acting through the same point) forces is if their resultant is zero;
- know that vectors representing forces in equilibrium form a closed polygon;
- understand how to solve problems involving equilibrium of a particle under coplanar forces, including particles on inclined planes and 2D vectors;
- be able to solve statics problems for a system of forces which are not concurrent (e.g. ladder problems), thus applying the principle of moments for forces at any angle.

Success Criteria

- ❑ You can solve problems involving motion on rough or smooth inclined planes.
- ❑ You can solve problems involving connected particles that require the resolution of forces

Assumed Prior Knowledge/ Links / Interleaving

<u>AS Mathematics – Mechanics</u>

- Kinematics (constant acceleration) (See Unit 7 of the SoW)
- Newton's laws of motion (See Unit 8 of the SoW)
- Basic equilibrium (See Unit 8 of the SoW)

Teaching Points

- This topic is a natural extension of AS Mathematics – Mechanics content which considers statics for systems whose forces are perpendicular (and do not need resolving at any angle) and **i**, **j** vector examples.
- Recall the previous definition of equilibrium: the vector sum of the forces is zero, so the sum of their resolved parts in any direction is zero.
- The book on an inclined plane provides the most common example of a weight on a slope. Stress the importance of key phrases like 'rough plane', which will introduce a frictional force. Also highlight the part of the sentence that says 'the book is *on the point* of moving *down* the plane' and emphasise that this indicates that the frictional force is in the up direction and is at its limiting value.

Cover examples

- Where the angle of incline is given in arctan or arcsin form, so students have to construct and read off sin and cos of the angle.
- Where weights are held in equilibrium by two strings at any angle (this is the same as a weight being tied onto a particular point of a single string – the knot makes it effectively two pieces of string with two different tensions).You could show an alternative graphical solution. For example, combining. the three forces to form a closed triangle (equilibrium means no resultant). Applying the sine rule to this triangle gives a useful result called Lami's theorem, but it can only be used for three forces in equilibrium.
- Where a ring is free to slide on a string (hence one tension).
- Where the forces are given in terms of **i** and **j**.
- Finally, move on to ladder-type problems which will revise moments and then extend to any angle, as the forces will not be concurrent. Extend the moments formula to '*perpendicular force* × *distance*' and resolve the force to find its component at right angles to the full distance from the moments point.
- Show students how to use the alternative formula '*force* × *perpendicular distance*', by measuring the perpendicular distance from the moments point to the line of action of the force.
- Also make sure that students are clear about the directions of the frictional force (for examples involving rough surfaces) and the reactions at the wall and ground being labelled differently.

Potential Barriers to Access /Misconceptions	**Opportunities for Reasoning/Problem Solving/Proofs**
• Students are often good at drawing force diagrams, but common errors are omitting arrowheads, incorrectly labelling (e.g. 4 kg rather than 4*g*) and missing off the normal reaction or friction forces. Students can sometimes struggle to work out the direction of the frictional force. • Common errors in questions involving moments are ignored the weight of the ladder, sine/cosine confusion and missing a distance in one or more terms.	• Extension: consider a uniform rod which has one end *freely hinged* to a wall and the other end tied to a point above the wall, making the bar horizontal. Discuss the fact that the reaction at the hinge is *not* perpendicular to the wall and that the lines of actions of all the forces in the system will all meet at one point for equilibrium. Representing the reaction at the hinge as two perpendicular forces, the 'resolving and taking moments' solution would be fairly straightforward. • The guidance on the specification document states 'Problems may be set where forces need to be resolved. (Restricted to forces in two perpendicular directions or simple cases of forces given as 2D vectors.)'
Key Mathematical Vocabulary	Force, resultant, component, resolving, plane, parallel, perpendicular, weight, tension, thrust, friction, air resistance, reaction, driving force, braking force, force diagram, equilibrium, inextensible, light, negligible, particle, rough, smooth, incline, uniform, friction, coefficient of friction, concurrent, coplanar.

Personal Development	**Notes**	**Resources**
Pupils are taught that they must show 'ambition' in their assignments by attempting to meet all criteria in their homework, with honesty with regards what support they have had to complete the assignment		