UNIT 441: STRUCTURAL MECHANICS

Lesson 1: Determination of beam reactions **Suggested Teaching Time:** 6 hours approx

Learning Outcome 1: Be able to determine reactions and forces, bending moments shear forces and deflections

Topic	Suggested Teaching	Suggested Resources
Determination of beam reactions (AC 1.1 and 1.2)	• Principle of moments. The basic principles should be demonstrated using simple equipment, and learners should be given the opportunity to test the principles practically. Whole-class teaching should reinforce the practical work to embed the concept that a moment of a force is the product of the magnitude of that force and the **perpendicular** distance between the turning point and the **line** of action of the force. Tutors must stress that it is **not** the actual distance between the **point** at which the force acts and the turning point that matters and, as above, this should be demonstrated practically. Learners should then be introduced to the 'principle of moments' – that clockwise moments and anti-clockwise moments are equal for co-planar systems in equilibrium ($\Sigma M = 0$). This too should be demonstrated practically and/or checked practically by learners in small groups. • Total load = total reaction. A tutor-led discussion should be used to extend the concept of static equilibrium to the realisation that, for systems in equilibrium, not only does $\Sigma M = 0$, but ΣV and ΣH also equal zero. That $\Sigma V = 0$ implies that the algebraic sum of all vertical forces equals zero, and that total loads equal total reactions in all cases. The discussion should then be directed towards an understanding of how this concept, together with the principle of moments, can be used to determine the value of reactions for loaded beams.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 Hulse R., Cain J., *Structural Mechanics* (Worked Examples) ISBN: 0230579817 **Practical equipment:** Beams, rules, hanging weights, pulleys, string **Software:** Goya Siemens PLM RISA Technology **Website:** www.istructe.org

UNIT 441: STRUCTURAL MECHANICS

Lesson 2: Determination of beam reactions (continued).	**Suggested Teaching Time:** 8 hours approx

Learning Outcome 1: Be able to determine reactions and forces, bending moments shear forces and deflections

Topic	Suggested Teaching	Suggested Resources
Determination of beam reactions (continued) (AC 1.1 and 1.2)	• Learners will need to practice drawing loading diagrams from provided information. Tutors should provide exemplars from which they can derive such diagrams, for both point and uniformly distributed loads. • Beam reactions for point loading on simply supported beams (with and without overhangs) and cantilevers. Whole-class teaching should be used to introduce the learners to how the principles learned earlier can be used to determine beam reactions for point loading only. The tutor should work through typical examples of such calculations and the learners should then work through other examples of such calculations. The tutor should provide feedback on the answers obtained and repeat the process until consistent answers are obtained. There are software packages that can do all this, and it would be useful for the learners to check their answers against those obtained from the software programmes, but this should not be considered as the preferred method of determining beam reactions at this stage. • Beam reactions for uniformly distributed loads (UDLs) as above. The tutor should demonstrate how a UDL can be considered as a point load by considering the load as concentrated at the centre of the loading. For instance, a UDL of 30 kN/m, extending over 4 m, can be considered as a point load of 120 kN acting 2 m from each end. • Beam reactions for combination of point loads and UDLs. As above, with the tutor working through typical examples, the learners attempting to solve similar problems and the tutor offering regular feedback until the learners can consistently solve such problems.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 Hulse R., Cain J., *Structural Mechanics* (Worked Examples) ISBN: 0230579817 **Practical equipment:** Proprietary rigs for testing shear force and bending moments **Software:** Goya Siemens PLM ANSYS **Website:** www.istructe.org

Lesson 3: Calculate shear force and bending moment values.	**Suggested Teaching Time:** 8 hours approx

Learning Outcome 1: Be able to determine reactions and forces, bending moments shear forces and deflections

Topic	Suggested Teaching	Suggested Resources
Determination of shear force and bending moment values (AC 1.1, 1.2, and 1.4) Determination of deflections at mid-span (AC 1.3)	• Whole-class teaching should be used to define the terms 'shear force' (SF) and 'bending moment' (BM) and to show how each can be determined at various points. This should be developed into the conversion of the values into 'SF diagrams' and 'BM diagrams'. • Small-group work should follow with each group being given different loading diagrams for a variety of loading conditions (point loads or UDLs or both, simply supported beams or cantilevers). The tutor should circulate around the groups, correcting any mistakes along the way. A whole class, tutor-led, discussion should follow, with the tutor leading the class towards (a) noting the coincidence of the bending moment maximum and shear force zero (b) the importance of the point of contraflexure, at which positive bending becomes negative bending (or vice-versa) and (c) the use to which the SF zero, BM max and position of the point of contraflexure are put. • Whole-class teaching should be used to demonstrate the importance of limiting the amount by which a beam deflects under load, and predicting the amount by which the beam will deflect under a given load, to see if this is in within acceptable limits. Tutors should use worked examples to illustrate the point and learners should have the chance to practice similar calculations, with tutors providing ongoing feedback. A sheet of the formulae used to determine deflection under a range of loadings should be made available. There is no requirement for learners to commit these formulae to memory.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 Hulse R., Cain J., *Structural Mechanics* (Worked Examples) ISBN: 0230579817 **Practical equipment:** Proprietary rigs for testing shear force and bending moments **Software:** Goya Siemens PLM ANSYS **Website:** www.istructe.org

Lesson 4: Determination of magnitude and type of forces in frameworks **Suggested Teaching Time:** 6 hours approx

Learning Outcome 1: Be able to determine reactions and forces, bending moments shear forces and deflections

Topic	Suggested Teaching	Suggested Resources
Determination of magnitude and type of forces in frameworks (AC 1.5)	• Bow's notation. The tutor should develop the system used to annotate frames and the learners should then have the opportunity to annotate a series of different frames. This should be checked by the tutor. • Graphical method of solving frames. This can be done manually or electronically. Whichever method is used, the tutor must stress the importance of accuracy in the drawing of both angles and lines. A discussion should follow in which the learners learn to differentiate between struts and ties from the direction of the forces in the individual force polygons joint. • Method of resolution. The tutor should demonstrate solving frames using horizontal and vertical static equilibrium at each joint. Learners should then practice on different frames with different loadings. • Method of sections. The tutor should demonstrate the procedures to use. A class discussion should ensue on where and when this method might be preferred to the other methods available, given that it is generally perceived to be more difficult. • Once again, there are software applications that can be used to solve frames and these can be used to check the learners' answers.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 Durka, F., et al *Structural Mechanics* ASBN: 0132239647 **Practical equipment:** Proprietary equipment for testing frames **Software:** Goya RISA Technology **Website:** www.istructe.org

Lesson 5: Design of simple beams **Suggested Teaching Time:** 8 hours approx

Learning Outcome 2: Be able to design simple beams and columns

Topic	Suggested Teaching	Suggested Resources
Design of simple beams (AC 2.1 and 2.2)	• General theory of bending. Learners should be able to use the formula to design simple beams. Tutors may derive the formula from first principles but learners are not required to do so. A simple hand-out will suffice. What is important is that learners understand the importance of the variables M, I, f and y, and of using consistent units. • First and second moments of area. Tutors must emphasise the importance of sectional shape in beam sizing. Learners must be aware of the various formulae required to determine the second moment of area (I) - also known as the 'moment of inertia' - although practice calculations should be restricted to beams of rectangular section for timber and concrete and universal beam sections for steel. Learners must be given the opportunity to determine moments of inertia by using the formulae and by extraction of the values from tables, once the section modulus (z) has been determined. • The class should be divided into several small groups and each should be given similar data to allow them to determine the required size of a beam. Comparing the answers will show that there are several beam sizes that satisfy the requirements for a given loading condition. • Tutor-led discussion about the effect of differences in breadth, depth and sectional shape should lead to an agreed conclusion concerning the most practical size of beam to be used, and why this is so.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 **Manuals** *Steel Designers' Manual* (SC1) *Code of Practice for Structural Use of Concrete* 2013 BS 5268-2:2002 *Structural Use of Timber: Part 2* **Software:** Goya Siemens PLM **Website:** www.istructe.org

Lesson 6: Design of simple columns **Suggested Teaching Time:** 6 hours approx

Learning Outcome 2: Be able to design simple beams and columns

Topic	Suggested Teaching	Suggested Resources
Design of simple axially loaded columns (AC 2.1 and 2.3)	• Factors to be considered. Whole-class teaching should be used to develop the concepts of effective length, slenderness ratio and radius of gyration and, as above, the sectional shape as quantified by the moment of inertia. Tutors should demonstrate how the above can be determined, by calculation and/or by extraction from the appropriate tables. In general, timber columns should be of rectangular or circular cross-section and steel columns should be of universal (H-section) or circular form. Learners must then practice determining the important factors for a variety of end conditions, and size and shape of columns, and in two perpendicular planes (X-X and Y-Y). • Design of simple columns. This should be restricted to axially-loaded columns. The tutor should demonstrate design calculations in timber, concrete and steel and the learners should practice these calculations, with regular feedback from the tutor, until the procedures are embedded. The calculations should include both the determination of the safe load for a given column, and the specification of a suitable column for given loads and end conditions. As is generally the case, the learners' answers can be checked using suitable software.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 **Manuals** *Steel Designers' Manual* (SC!) *Code of Practice for Structural Use of Concrete* 2013 BS 5268-2:2002 *Structural Use of Timber: Part 2* **Software:** Goya Siemens PLM

Lesson 7: Determining forces and pressures on retaining walls **Suggested Teaching Time:** 4 hours approx

Learning Outcome 3: Be able to calculate pressures and factors of safety on retaining walls

Topic	Suggested Teaching	Suggested Resources
Determining forces and pressures on retaining walls (AC 3.1)	• Retaining walls. Small group work would be useful here, with each group being given examples of retaining walls of different design (rectangular and trapezoidal), different materials (concrete, brick and stone) and different dimensions. Learners should determine the load due to the wall and the position at which the load can be considered as acting. Each group should then make a presentation of how they arrived at their answers, with their peers directing questions at them and commenting upon the answers. The tutor should lead on this. • Whole-class teaching should be used to introduce the concepts of pressure at depth, depth of centre of pressure and Rankine's Coefficient. The tutor should work through examples for both retained water and soils and learners should practice similar calculations. • The final outcome should be an understanding of the magnitude of the load on the ground due to the wall, the position at which this load is considered to act, the magnitude of the force acting on the retaining wall and the position at which this force is considered to act. The learners should be able to determine these factors for a range of retaining walls and for different retained materials. A class discussion should follow concerning the use to which this information could be put and the different ways in which the retaining walls may fail in use.	**Books:** Hulse, R.., Cain, J., *Structural Mechanics* ISBN: 0333804570 Hulse R., Cain J., *Structural Mechanics* (Worked Examples) ISBN: 0230579817 **Software:** Goya Siemens PLM **Website:** www.istructe.org

Lesson 8: Factors of safety and stress conditions for retaining walls **Suggested Teaching Time:** 8 hours approx

Learning Outcome 3: Be able to calculate pressures and factors of safety on retaining walls

Topic	Suggested Teaching	Suggested Resources
Factors of safety and stress conditions for retaining walls (AC 3.2 and 3.3)	• A practical demonstration with models of retaining walls will show how retaining walls can fail by sliding, overturning or excessive pressure on the ground. A tutor-led class discussion should be used to lead the learners to a consideration of the factors needed to determine the factors of safety for each mode of failure under given conditions. • Whole-class teaching should be used to introduce the relatively simple techniques used to determine the factors of safety against sliding and overturning. Tutors should work through typical examples and learners should then practice similar calculations. A class discussion should follow concerning whether the factors of safety are adequate in each case, given the situations and materials used. • The class discussion should be extended to a consideration of the turning effect on the wall as a result of the retained material and how this will affect the distribution of stress on the ground, particularly at the toe and heel of the wall. The tutors should work through typical examples and learners should then practice similar calculations. The class discussion should then consider whether this will compromise the effectiveness of the wall, and if so how.	**Books:** Hulse R., Cain J., *Structural Mechanics* (Worked Examples) ISBN: 0230579817 **Practical equipment:** As described **Software:** Goya Siemens PLM RISA Technology **Website:** www.istructe.org