

Cambridge **TECHNICALS LEVEL 3**



ENGINEERING

Unit 3

Principles of mechanical engineering

Y/506/7268

Guided learning hours: 60

Version 3 October 2017 - black lines mark updates



LEVEL 3

UNIT 3: Principles of mechanical engineering

Y/506/7268

Guided learning hours: 60

Essential resources required for this unit: Formula Booklet for Level 3
Cambridge Technicals in Engineering, scientific calculator and ruler (cm/mm)

This unit is externally assessed by an OCR set and marked examination.

UNIT AIM

All machines and structures are constructed using the principles of mechanical engineering. Machines are made up of components and mechanisms working in combination. Engineers need to understand the principles that govern the behaviour of these components and mechanisms. This unit explores these principles and how they are applied.

By completing this unit learners will develop an understanding of:

- systems of forces and types of loading on mechanical components
- the fundamental geometric properties relevant to mechanical engineering
- levers, pulleys and gearing
- the properties of beams
- the principles of dynamic systems

TEACHING CONTENT

The teaching content in every unit states what has to be taught to ensure that learners are able to access the highest grades. Anything which follows an i.e. details what must be taught as part of that area of content. Anything which follows an e.g. is illustrative.

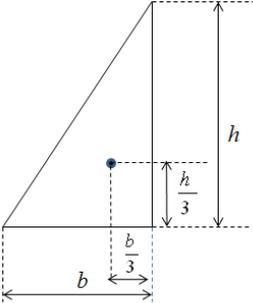
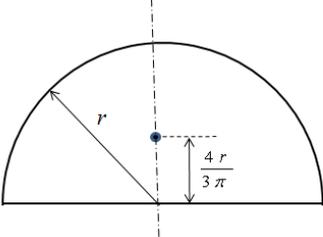
For externally assessed units, where the teaching content column contains i.e. and e.g. under specific areas of content, the following rules will be adhered to when we set questions for an exam:

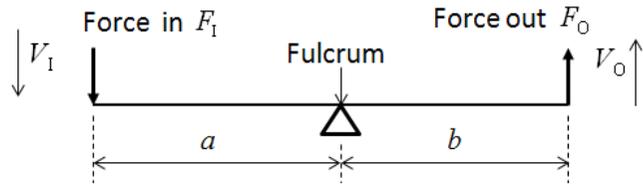
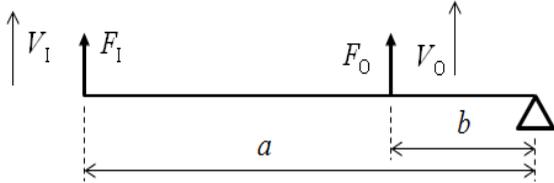
- a direct question may be asked about unit content which follows an i.e.
- where unit content is shown as an e.g. a direct question will not be asked about that example.

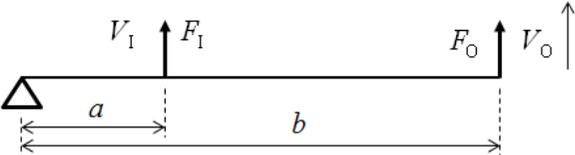
Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
1. Understand systems of forces and types of loading on mechanical components	1.1 different types of loading that could be applied to a mechanical component <ul style="list-style-type: none"> • direct forces • turning forces, i.e. <ul style="list-style-type: none"> ○ moments ○ torque • shear forces 1.2 to resolve a force into its orthogonal components. 1.3 systems of co-planar forces, i.e.: <ul style="list-style-type: none"> • concurrent forces • non-concurrent forces 	Learners should appreciate the different types of loading identified, and how they can be applied to a mechanical component. Methods of trigonometry should be used to resolve forces. Learners should understand situations in which assumptions of particle and rigid body mechanics can be applied. Learners should be able to use and draw force diagrams to represent engineering problems to aid visualisation and analysis.

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
	<p>1.4 diagrammatic representations of engineering problems using force diagram</p> <p>1.5 how mechanical engineering situations can be represented by:</p> <ul style="list-style-type: none"> • particle mechanics • rigid bodies <p>1.6 conditions of equilibrium for systems of forces</p> <p>1.7 how to determine the resultant of a set of co-planar forces and hence determine the equilibrant of those forces</p> <p>1.8 how materials respond to direct axial loading, both in tension and compression</p> <p>1.9 the terms stress, strain and Young's modulus, and application of formulae to calculate direct stress and strain in axially loaded components i.e.:</p> <ul style="list-style-type: none"> • stress = force/cross-sectional area • strain = change in length/original length • use of Young's modulus (E) = stress/strain 	<p>Learners should be aware of horizontal and vertical equilibrium for systems of concurrent forces (particle mechanics), and horizontal, vertical and rotational equilibrium for non-concurrent forces (rigid body mechanics).</p> <p>For systems of concurrent forces the resultant or equilibrant force should be defined in terms of magnitude and direction.</p> <p>For systems of non-concurrent forces the learner must be able to define the resultant or equilibrant both in terms of :</p> <ol style="list-style-type: none"> 1. magnitude and line of action (point and direction) 2. magnitude and direction, and moment acting at a specific point <p>Learners should be aware of the assumptions made for calculations of direct stress and strain in axially loaded components. They should know appropriate units for stress and Young's modulus and be able to use the formulae listed to carry out calculations for components in direct tension or compression.</p> <p>Learners must know the term of the modulus of elasticity (Young's modulus), and that this represents the stiffness of a material.</p>

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
	<p>1.10 representation of material behaviour on a generic stress versus strain graph i.e.:</p> <ul style="list-style-type: none"> • elastic deformation • the elastic limit • in-elastic and plastic deformation • ultimate stress • factor of safety <p>1.11 how to apply formulae to calculate the shear stress in a component under shear loading i.e.</p> <ul style="list-style-type: none"> • $\text{shear stress} = \text{shear force} / \text{shear area}$ 	<p>Learners must be able to identify key points from, and interpret material behaviour on a generic stress versus strain graph.</p> <p>Learners should understand why engineers usually design components to keep stress levels below the elastic limit and the implications for the behaviour of the component if the operational stress levels exceed the elastic limit.</p> <p>Learners should understand how Factors of Safety (FOS) are used to calculate the allowable working stress of a material i.e.</p> <ul style="list-style-type: none"> • $\text{allowable working stress} = \text{ultimate stress} / \text{FOS}$ <p>Learners should understand the terms shear stress and shear strain. Learners should be aware of components in single and double shear (e.g. a bolt).</p>
2. Understand fundamental geometric properties	<p>2.1 calculation of the area of irregular 2D shapes</p> <p>2.2 calculation of the volume of a regular prism of known cross sectional area and length</p>	<p>Irregular shapes formed by the addition (or subtraction) of regular shapes (rectangle / triangle / circle). These will be presented in the form of engineering problems, e.g. calculate the cross-sectional area of a beam.</p>

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
	<p>2.3 calculation of the mass of a body of known volume and uniform density</p> <p>2.4 the significance of the centroid of a body as its centre of gravity/centre of mass</p> <p>2.5 the use of axes of symmetry of a uniform 2D figure to find its centroid</p> <p>2.6 the position of the centroid of common non-symmetrical 2D shapes i.e.</p> <ul style="list-style-type: none"> • right-angled triangle • semi-circle <p>2.7 the use of moment of area of uniform regular 2D shapes to find the position of the centroid of more complex uniform irregular shapes</p>	<p>All centroid questions will be based on 2D shapes of uniform density.</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <p>More complex shapes may be the result of addition or subtraction of rectangles, right-angled triangles and semi-circles.</p> <p>Questions may include calculation of resultant forces or equilibrium of 2D components using knowledge from LO1 of this unit.</p>

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
<p>3. Understand levers, pulleys and gearing</p>	<p>3.1 concepts of mechanical advantage (MA) and velocity ratio (VR) applied to:</p> <ul style="list-style-type: none"> • levers • systems of pulleys • gears <p>3.2 the three classes of lever i.e.</p> <ul style="list-style-type: none"> • class one • class two • class three 	<p>Learners should understand that MA and VR are inversely related so that an increase in output force (force amplification) or torque (torque amplification) is achieved at a cost of output speed. Levers (direct forces and linear movements) and gears or pulley systems (for torque and rotational movement) obey the same fundamental principles.</p> <p>Learners should be able to recognise different types of levers as part of simple mechanisms and identify the key features of fulcrum, input force (F_I) and output force (F_O). Learners must be able to carry out calculations to determine unknown forces, the mechanical advantage and/or velocity ratio for levers of given geometry (input velocity V_I, output velocity V_O).</p> <p>Class one lever</p>  <p>Class two lever</p> 

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
		<p>Class three lever</p>  <p>Mechanical Advantage (MA) = $F_0/F_1 = a/b$ Velocity Ratio (VR) = $V_0/V_1 = b/a$</p>
	<p>3.3 different types of gears and gear systems, and their applications i.e.:</p> <ul style="list-style-type: none"> • spur gears • compound spur gears • idler gears • chain driven sprockets • bevel gears • rack and pinion • wormgear and wormwheel <p>3.4 calculation of MA and VR for spur gears</p> <p>3.5 calculation of MA and VR for simple compound spur gear systems</p> <p>3.6 different types of pulley and belt drive systems and their applications i.e.:</p> <ul style="list-style-type: none"> • V-belts • flat belts • toothed belts <p>3.7 calculation of the MA and VR for the named belt drive systems above</p>	<p>Learners should be able to identify different types of gear systems and suggest applications for which they are commonly used.</p> <p>MA = $\frac{\text{Number of teeth on output gear}}{\text{Number of teeth on input gear}}$</p> <p>VR = $\frac{\text{Number of teeth on input gear}}{\text{Number of teeth on output gear}}$</p> <p>Questions will be limited to a gear train of no more than 4 gears.</p> <p>Learners should be able to identify different types of pulley and belt systems and their advantages and disadvantages for common applications.</p> <p>MA = $\frac{\text{Diameter of output pulley}}{\text{Diameter of input pulley}}$</p> <p>VR = $\frac{\text{Diameter of input pulley}}{\text{Diameter of output pulley}}$</p>

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
<p>4. Understand properties of beams</p>	<p>4.1 different types of beams and their support conditions. i.e.:</p> <ul style="list-style-type: none"> • simply supported • cantilever • continuous • encastre <p>4.2 different types of loading applied to beams i.e.:</p> <ul style="list-style-type: none"> • point loads • uniformly distributed loads <p>4.3 how to calculate, using conditions of static equilibrium, the reactions of beams. i.e.:</p> <ul style="list-style-type: none"> • simply supported • cantilever <p>4.4 how to calculate the bending moment at any point in simply supported or cantilever beams with point loading</p> <p>4.5 how to draw a bending moment diagram for a simply supported or cantilever beam with point loading</p>	<p>Questions involving calculations will be restricted to statically determinate beams only (i.e. simply supported and cantilever beams).</p> <p>Learners should understand that uniformly distributed loads can be imposed loads e.g. pedestrians or dead loads from the weight of the beam.</p>

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
5. Understand principles of dynamic systems	5.1 how to apply Newton's Laws of Motion in a mechanical engineering context 5.2 how to apply the constant acceleration formulae to problems set in a mechanical engineering context i.e.: <ul style="list-style-type: none"> • $v^2 = u^2 + 2as$ • $s = ut + \frac{1}{2}at^2$ • $s = vt - \frac{1}{2}at^2$ • $v = u + at$ • $s = \frac{1}{2}(u + v)t$ 5.3 the principle of conservation of energy and how to apply this principle to problems involving kinetic and gravitational potential energy 5.4 the relationship between work done on a body and the change in energy of that body	Questions will be based on a variety of scenarios i.e. <ul style="list-style-type: none"> • linear motion • collisions • projectiles • motion on inclined planes

Learning outcomes	Teaching content	Exemplification
The Learner will:	Learners must be taught:	
	<p>5.5 application of equations for energy and work done to problems set in a mechanical engineering context i.e.:</p> <ul style="list-style-type: none"> • gravitational potential energy $E_p = mgh$ • kinetic energy $E_k = \frac{1}{2}mv^2$ • work done = force x distance <p>5.6 use of the equations for power to solve problems set in a mechanical engineering context i.e.:</p> <ul style="list-style-type: none"> • instantaneous power = force x velocity • average power = work done/time <p>5.7 the action of a friction force between a body and a rough surface and how to apply the equation $F \leq \mu N$</p> <p>5.8 to apply the principle of conservation of momentum to bodies experiencing elastic collisions</p>	

ASSESSMENT GUIDANCE

All Learning Outcomes are assessed through externally set written examination papers, worth a maximum of 60 marks and 1 hour and 30 minutes in duration. Learners should study the design requirements, influences and user needs within the taught content in the context of a range of real engineered products. Exam papers for this unit will use engineered products as the focus for some questions, however it is not a requirement of this unit for learners to have any detailed prior knowledge or understanding of particular products used. Questions will provide sufficient product information to be used, applied and interpreted in relation to the taught content. During the external assessment, learners will be expected to demonstrate their understanding through questions that require the skills of analysis and evaluation in particular contexts.

LEARNING OUTCOME WEIGHTINGS

Each learning outcome in this unit has been given a percentage weighting. This reflects the size and demand of the content you need to cover and its contribution to the overall understanding of this unit. See table below:

LO1	20-30%
LO2	10-20%
LO3	15-25%
LO4	10-20%
LO5	20-30%

*SYNOPTIC ASSESSMENT AND LINKS BETWEEN UNITS

Ten per cent of the marks in each examination for this unit will be allocated to synoptic application of knowledge. There'll be questions that draw on knowledge and understanding from Unit 1 Mathematics for engineering and/or Unit 2 Science for engineering that then has to be applied in the context of this unit.

To find out more
ocr.org.uk/engineering
or call our Customer Contact Centre on **02476 851509**
Alternatively, you can email us on **vocational.qualifications@ocr.org.uk**



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