Unit 13: Principles and Applications of Fluid Mechanics

Unit code: H/600/0263

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will give learners an understanding of the behaviour and characteristics of engineering fluids and their application in hydrostatic and dynamic fluid systems.

Unit introduction

Hydraulic and pneumatic power is widely used in the operation of engineering systems. The brakes on motor vehicles, railcar doors and hydraulic actuators and presses are typical examples. Fluid power is also widely used on aircraft, particularly for lowering and raising the undercarriage and for operating the flight control surfaces.

The study of this unit will introduce learners to a range of concepts and applications of fluid mechanics that will enable them to solve engineering problems associated with fluid systems.

The unit will provide learners with an understanding of surface tension and the viscous behaviour of Newtonian fluids that will then be used to determine a range of parameters in bearing systems. Learners will be introduced to the characteristics and behaviour of fluids at rest and will apply this knowledge to the inputs and outputs of hydraulic devices and systems, as well as to the determination of thrust forces and pressures that act on immersed rectangular and circular surfaces.

Learners will be introduced to fluid flow in piped systems and to the measurement of flow velocities, pressures and energy, using a variety of measuring instruments. The behaviour of fluid jets will be studies, in particular the jets from nozzles that impinge on stationary vanes, will be considered. This knowledge will be useful as a precursor to the study of turbo-machines, should they choose to go onto more advanced fluid studies. Finally a study of the concepts associated with the wind tunnel testing of models, that find use in the design and testing of motor vehicles and aircraft, when subject to external fluid flows, will be made.

Learning outcomes

On completion of this unit a learner should:

1 Understand the physical properties and characteristic behaviour of fluids and system parameters for oiled bearings

2 Be able to determine the parameters that act in hydrostatic devices and act on immersed surfaces

3 Be able to apply fluid flow theory to determine parameters for piped measuring systems and nozzle vane systems

4 Understand the use of wind tunnel testing, aerodynamic theory and associated test data to determine the aerodynamic parameters of test models.

Unit content

1 Understand the physical properties and characteristic behaviour of fluids and determine system parameters for lubricated bearings

Physical properties: eg surface tension (surface tension coefficient, capillary action), viscosity (dynamic viscosity, coefficient of dynamic viscosity, kinematic viscosity, variation in viscosity with temperature)

Characteristic behaviour: eg Newtonian fluids (water, lubricating oils) and non-Newtonian fluids (pseudo plastic, Bingham plastic, Casson plastic, dilatent)

Bearings: eg plain journal, plain thrust; system parameters eg bearing dimensions, speed, viscosity of lubricant, viscous resistance, power loss

2 Be able to determine the parameters that act in hydrostatic devices and act on immersed surfaces

Hydrostatic devices: devices eg hydraulic actuator, Bramah press, hydraulic braking system; system parameters eg cylinder dimensions, input and output forces, internal pressure, input and output motions

Immersed surfaces: surfaces eg retaining walls of tanks and reservoirs, lock and sluice gates, immersed rectangular and circular inspection covers and hatches; system parameters eg surface dimensions, depth of immersion, hydrostatic pressure and thrust, position of centre of pressure

3 Be able to apply fluid flow theory to determine parameters for piped measuring systems and nozzle vane systems

Fluid flow theory: eg incompressible flow, equations of continuity of mass and volume, Bernoulli's equation, Reynolds number, turbulent and laminar internal flows, use of D'Arcy's equation

Piped measuring systems: eg standard pipe lengths, tapered pipes, inclined and tapered pipes, measuring instruments (such as venture meter, orifice meter, manometer, Pitot-static tube; parameters eg mass and volume flow rates, entry and exit velocities, pressure energy changes

Nozzle vane systems: eg stationary nozzle, normal impinging jet, stationary vane (such as flat plate, hemispherical cup, reaction jet); parameters (thrust forces exerted by a jet, normal impinging forces on vanes, reaction of a jet nozzle)

4 Understand the use of wind tunnel testing, aerodynamic theory and associated test data to determine the aerodynamic parameters of test models

Wind tunnel testing: equipment eg open-section, closed section tunnels, smoke tubes, test data measuring devices (such as digital instruments, speed probes, pitot-static tubes, manometers); test models eg aerofoil sections, fixed wing scale model aircraft, rotary wing scale model aircraft, scale model racing cars and spoilers

Aerodynamic theory: definitions, formulae and evaluation eg external flow around bluff bodies, angle of attack, span, chord, aspect ratio, wing area, airspeed, stall conditions, lift and drag coefficients, dynamic pressure, drag force, lift force, lift/drag ratio, significance of model size, Reynolds number, wind-tunnel pressurisation and speeds and scale effect

Aerodynamic parameters: eg pressure distribution, lift and drag coefficients, lift, drag, down force, lift/drag ratio from theory and test data readings

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria					
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**		**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**	
P1	determine the surface tension coefficient for a given liquid on glass from its rise in a capillary tube	**M1**	calculate the viscous resistance and power loss in a lubricated plain thrust bearing from given data	**D1**	explain, compare and contrast, the behaviour of the range of non-Newtonian fluids when they are subjected to shearing forces
P2	explain how the viscosity of Newtonian fluids is affected by changes in temperature and pressure	**M2**	determine whether the difference in levels between reservoirs connected by a pipe of given length and diameter is sufficient to supply a given flow rate	**D2**	investigate and evaluate the Venturi meter, orifice meter and Pitot-static tube for the measurement of fluid flow.
P3	calculate the viscous resistance and power loss in a lubricated plain journal bearing from given system parameters	**M3**	determine, using given test data, the value of Reynolds number at which a particular flow pattern occurs around a model structure and determine the velocity at which the same pattern is likely to occur around the actual structure		
P4	determine the output force and motion of a hydrostatic device from given system parameters	**M4**	explain the change in the flow pattern, pressure distribution and the lift and drag coefficient for an aerofoil as its angle of attack is increased up to the stall		
P5	determine the thrust on and centre of pressure position of, an immersed vertical retaining surface whose top edge is below the free surface of the retained liquid	**M5**	explain the significance of down force and how down force may be increased by design features, on high speed racing cars.		
P6	determine the flow velocities at the inlet and exit sections of an inclined tapering pipe, using fluid flow theory and given pressure readings and flow rates				

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P7 determine the resultant thrust and the reaction of the jet nozzle, when a jet of fluid impinges normally on a stationary flat plate		
P8 describe the wind-tunnel equipment set-up and experimental measurements needed to produce a pressure distribution plot of an aerofoil section at a fixed angle of attack		
P9 determine the dynamic pressure exerted on a wind tunnel model and its drag coefficient using aerodynamic theory and given test data [IE3].		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers CT – creative thinkers	RL – reflective learners TW – team workers	SM – self-managers EP – effective participators

Essential guidance for tutors

Delivery

This unit has been written in a way that minimises the need for expensive and in some cases highly specialised laboratory and workshop practical equipment. However, whenever and wherever possible a practical investigative approach to learning should be adopted by centres. A minimum equipment list is given in the 'Essential resources' and learners will need access to this equipment in order to achieve the unit outcomes. The learning experience would also be very much enhanced if learners were able to have access to, or observe demonstrations on some or all of the 'Recommended resources'.

The four learning outcomes are ordered logically and it would be reasonable to deliver them sequentially. In this way learners will be able to apply their knowledge of Newtonian fluids and in particular the viscous behaviour of these fluids to the determination of hydrostatic and dynamic fluid system parameters.

Delivery of learning outcome 1 might start with a general description of compressible and incompressible fluid properties. Then, the phenomena of surface tension and calculation of capillary effects can be explained in detail and reinforced by a tutor-led practical demonstration and/or practical laboratory exercises to determine surface tensions for a given variety of fluids.

The study of dynamic and kinematic viscosity and its measurement in SI units (International System of units) might be accompanied by mention of other measuring systems, for example SAE classification for lubricating oils and systems specific to particular items of apparatus, such as the Redwood viscometer. Knowledge of the nature and viscosity of Newtonian fluids may then be applied to the theoretical determination of the viscous resistance and power dissipation of machine slides and/or plain bearings. An investigative approach to the range of non-Newtonian fluids and their behaviour and rheograms should be encouraged. Learners should be able to give a qualitative explanation of their behaviour, citing examples of each type.

Delivery of learning outcome 2 might include demonstrations and familiarisation with hydrostatic systems and equipment such as hydraulic test rigs and/or vehicle braking systems (both hydraulic and pneumatic). This will reinforce the theoretical determination of system parameters, such as input/output forces, internal pressures and movement of system devices.

When considering the thrust forces and pressures that act on submerged surfaces, learners will need to be familiar with the concept of second moment of area. They may have encountered this concept before in their previous study of mechanical principles and/or mathematics, where it may have been presented as an application of the integral calculus. Failing this, the expressions for second moment of area will need to be derived for a rectangle and a circle about a plain axis through the centroid and about a parallel axis, making use of the parallel axis theorem, so that an expression for the depth of the centre of pressure of an immersed plane surface can then be derived. Associated problems that include the determination of the thrust and its line of action for immersed rectangular and circular retaining surfaces may then be solved. These problems might include applications concerned with, inspection covers, sluice gates and hatches that are immersed at some distance below the free surface of the retained liquid, requiring the determination of the load on their fixings.

When delivering the fluid flow theory for learning outcome 3, a useful start could be made by revising the concept of continuity that learners will have covered in *Unit 5: Mechanical Principles and Applications*. Learners will then need to consider the energy forms that may be present in a fluid. Although learners should be familiar with the expressions for gravitational potential energy and kinetic energy, the concept of pressure-flow energy may well need to be explained and developed.

There are different approaches to the derivation of Bernoulli's equation but it may be beneficial to begin by developing the full steady flow energy equation. Then, Bernoulli's equation may be derived directly from this and applied to the solution of problems on pipeline flow and differential pressure flow measuring devices.

A practical investigative approach would be used when considering the role of measuring instruments in piped systems, particularly the venture meter, orifice meter and direct float meter. All of these meters form part of the Bernoulli fluid flow apparatus, when used in conjunction with a metered flow tank. This practical investigative work could then form part of that needed for learning outcome 4.

Problems on pipeline flow should include the consideration of head loss due to pipe friction. This will warrant a discussion of laminar and turbulent flow, fluid viscosity and the associated boundary layer effects. D'Arcy's formula should be introduced as a means of estimating friction head loss and be applied to problems involving the steady flow due to gravity between reservoirs at different levels. A revision of Newton's laws may be necessary before applying them to determine the reaction of a jet nozzle and the thrust of an impacting fluid jet. The derived expressions may be applied successively to problems involving the impact of a jet on a stationary flat plate, hemispherical cup, and a pipe bend. Practical investigations of, laminar and turbulent flow and the impact of a jet would again, be of value to reinforce delivery of the theoretical and nozzle vane systems aspects of this outcome.

The delivery of the aerodynamic theory for learning outcome 4 would be enhanced by practical investigations involving smoke tunnels, Reynolds apparatus and wind-tunnel test facilities. Failing this, the use of video footage showing the onset of turbulence and formation of flow patterns in wind tunnels and flow tanks, would most certainly be useful.

Areas of the theory that should be emphasised include the effects of inertia and viscous resistance and the concept of Reynolds number for internal and external flows. The value of Reynolds number for fully developed laminar flow in pipes and over aerofoil sections should be identified and its corresponding use in flow tank and wind tunnel testing explained. Flow around a cylindrical body and other shapes should also be described, in the absence of smoke tunnels or other practical visualisation methods and the values of Reynolds number associated with changes of flow pattern should also be given.

A description of the use and operation of the Pitot-static tube in measuring flow velocities, should be given, again learning would be enhanced if access to this hardware was available. The identification of the factors that contribute to the drag force on a bluff body in a fluid stream and the relative effects of form drag and skin friction drag should be discussed followed by derivation of the expressions for dynamic pressure and drag coefficient. Problems to determine drag coefficient from wind-tunnel test data can then be solved. Again learning would be enhanced if learners were able to carry out their own practical investigations and determine these lift and drag parameters for themselves.

An explanation of aerofoil geometry should be confined to the basic profile and the symbols commonly used for chord, span, projected plan area and angle of attack.

Pressure distribution and airflow diagrams for normal flight and stalled condition should be presented and explained or if possible, plots for varying angles of attack could be determined experimentally using an open section wind tunnel and manometer measuring equipment. No matter how these plots are obtained, they may then be used to derive expressions for lift and drag forces in terms of the dynamic pressure, projected plan area and the lift and drag coefficients. Typical values of lift and drag coefficient for increasing angle of attack up to the stalled condition, might be presented graphically. Problem solving might include the determination of the lift and drag forces on aircraft and drag on racing cars or other high performance land vehicles.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit content, overview of activities and assessment strategy, issue of scheme of work/ assessment plan • surface tension – test tube and liquid demonstration • introduction to the nature and determination of dynamic and kinematic viscosity and its behaviour. Demonstration using Redwood viscometer or similar. *Learner activities*: • practical laboratory investigations and classroom problem solving sessions. *Whole-class teaching*: • theory and examples/demonstration of non-Newtonian shear thinning (pseudo-plastic) and shear thickening (dilatants) • examples of journal and thrust bearings. Example problems to determine parameters. *Learner activities*: • investigate the viscous behaviour of Newtonian fluids and non-Newtonian fluids with temperature and pressure changes.
Prepare for and carry out **Assignment 1: Nature of Fluids and Bearing Systems** (P1, P2, P3, M1, D1).
Whole-class teaching: • theory of fluids under pressure in hydraulic/pneumatic devices. Workshop/laboratory/fluid rigs – demonstration of system inputs/outputs/system parameters. *Learner activity*: • group and individual investigation/problem solving on apparatus or paper based. *Whole-class teaching*: • hydrostatic theory and in-class problem solving. *Learner activity*: • attend organised visit to view one or more of; canal lock gates, sluices, waterwheels, dams/reservoirs, swimming pools, pressurised container manufacturers or any similar set-up, to gain sense of scale and assist with problem solving exercises, by visualising dimensions, pressures and positions of centre of pressure, on full scale devices.
Prepare for and carry out **Assignment 2: Hydrostatic Devices and Immersed Surfaces** (P4, P5).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • fluid flow theory and piped measurement systems. Laboratory/workshop demonstrations to reinforce theory (eg regular section and tapered section pipes, Reynolds apparatus, Bernoulli apparatus, water tank measuring equipment, Venturi apparatus, manometers). *Learner activities*: • group and individual theoretical problem solving. Group experimental work on centre apparatus to ascertain measurement system parameters and reinforce theory. *Whole-class teaching*: • nozzle/vane system parameters, with examples of the hardware. *Learner activities*: • solve problems and investigate application of nozzle/vane applications in machinery.
Prepare for and carry out **Assignment 3: Piped Measuring and Nozzle Vane Systems** (P6, P7, M2, M3).
Whole-class teaching: • familiarisation with wind tunnels, associated equipment and measuring instruments. Either through audio-visual presentation or preferably, a site visit to wind-tunnel facilities • theory of data measuring instruments (including Pitot-static probe/instruments), their function, operation and theoretical methods to determine measurement parameters • explain aerodynamic theory determine parameters associated with aerofoil sections, bluff bodies, aerodynamic models. *Learner activities*: • use aerodynamic theory to determine aerodynamic parameters, from set theoretical problems • carry out (if possible) practical investigations using wind-tunnels, wind tunnel equipment and measuring instruments, to ascertain aerodynamic parameters.
Prepare for and carry out **Assignment 4: Determining Aerodynamic Parameters** (P8, P9, P10, M4, M5, D2).
Feedback on assessment, unit review and evaluation.

Assessment

Assessment evidence for t this unit may be collected from a series of four assignments. The precise nature of the practical aspects of these assignments will be partly or wholly dependent on the available physical resources. However, the assessment guidance detailed below is based on learners having access, on or off site, to the minimum equipment requirements needed to satisfactorily achieve the unit outcomes and grading criteria.

Assuming that the unit is delivered in the same order as the outcomes, learners must first demonstrate an understanding of the physical properties, in particular surface tension and viscosity (P1) and characteristic behaviour (P2) of Newtonian and non-Newtonian fluids, with only Newtonian fluids being subject to quantitative analysis.

Then learners are required to calculate the viscous resistance and power loss in plain journal bearing (P3) and plain thrust bearing (M1). Finally they must compare and explain the behaviour of a range of non-Newtonian fluids when they are subject to shearing forces (D1).

Evidence demonstrating achievement of the above assessment criteria for this outcome could come from the answers to a written/investigative assignment. This assignment could be set in two parts, whereby learners would first be required to answer a set of formal written tasks (P1, P2, P3, M1) and then carry out a literature search investigation for (D1). The tasks for the formal written part of the assessment would require learners to first develop and apply the expression used to determine surface tension coefficient from the rise of liquid in a capillary tube (P1). Next, learners would be required to explain how the viscosity of Newtonian fluids is affected by changes in temperature and pressure (P2), citing examples. Learners would then need to consider a plain journal bearing where they are progressively required, to determine the lubricated area and shearing velocity to meet a series of viscous resistance and power loss requirements (P3). Finally, learners are required to apply the integral calculus to determine the same parameters as above but for a plain thrust bearing.

For the investigative part of the assignment learners would need to carry out a literature search in order to explain, compare and contrast the behaviour (supported by the appropriate rheograms) of the non-Newtonian fluids identified in the unit content.

For learning outcome 2 learners must be able to determine output and input parameters such as force and motion, for hydrostatic devices (P4) and be able to determine the thrust and pressure acting on immersed surfaces (P5). Evidence for these criteria could come from the learner's answer to a second written assignment. Appropriate responses to tasks associated with the determination of output parameters for a hydraulic press, jack or braking system, would provide evidence that P4 had been met. Learners would then need to determine the thrust and centre of pressure position of immersed surfaces to meet P5.

To achieve learning outcome 3 learners must be able to determine the inlet and exit parameters for an inclined tapering pipe, within a piped system, using flow theory and given system data (P6). They will also need to able to determine the resultant thrust and nozzle reaction forces for a jet of fluid impinging normally on a stationary flat plate (P7). These criteria could be covered using a third written assignment which could also include additional tasks to meet M2 and M3.

Suitable tasks to meet criteria M2 could involve the calculation of the likely head loss along a pipe connecting two reservoirs using D'Arcy's formula. The pipe friction coefficient should be given and the estimated friction head loss compared to the potential head difference between the reservoirs. A judgement can then be made as to whether the required flow rate is feasible without the installation of a pump.

The test data required for a task to achieve M3 should include the control dimensions of the test model and actual structure. The model could be of any bluff body such as a cylinder or bridge pier around which a turbulent flow pattern is seen to occur at some particular value of flow velocity. The dynamic viscosity and density of the fluid should also be supplied. If wind-tunnel facilities are available, with appropriate smoke generators or other visualisation equipment, the airflow round the bluff body model could be assessed visually at different velocities.

A final assignment could cover P8, P9, P10, M4, M5 and D2. This assignment should ideally be designed around the use and completion of practical activities, with the minority of the criteria requiring a response to written tasks. The following describes how the appropriate criteria could be met through practical exercises, although it is appreciated that centres may not have all of the relevant equipment. Where this is the case a written task may be used instead.

Tasks to achieve (P8) require learners to describe a wind-tunnel set-up and detail the experimental measurements needed to create a pressure plot for an aerofoil section. Learners can meet this criterion through a written task, although it would assist them to see the equipment first hand.

To achieve P9, learners would benefit from obtaining the experimental measurements practically, rather than being given them. They would need to use a wind-tunnel or wind-tunnel model (such as a building, aircraft or scale model motor vehicle) and take appropriate readings from manometers, velocity meters, Pitot-static probes etc, as well as know the frontal area of the model under test. They could then apply aerodynamic theory to determine the dynamic pressure and drag coefficient.

In order to achieve M4, learners are required to explain the change in flow pattern, pressure distribution and the lift and drag coefficients for an aerofoil, with increasing angle of attack. Their explanation could be enhanced if learners have the opportunity to observe equipment where the changes across the aerofoil section can take place and so take the necessary readings from experiment. Failing this learners could be given a written task, where they are required to investigate and report on the required changes that take place with the aerofoil, as the angle of attack is gradually increased. An investigative task requiring written answers could be set in order to provide evidence for the achievement of M5, where learners are required to identify and explain the design features that are used on high performance racing cars, to increase down force.

Finally, a task requiring learners to undertake a practical investigation and evaluate the Venturi meter, orifice meter and Pitot-static tube and write a report on their findings, would be the most appropriate way of providing evidence for D2. If this is not possible then a practical assessment of one or more of these instrument plus a theoretical assessment of the others, would be the next best alternative. Irrespective of whether or not a practical or theoretical task is set, reference should be made in their written response to the typical applications, flow impedance, ease of installation, cost and sensitivity of each of these instruments, backing up their argument with technical data.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Nature of Fluids and Bearing Systems	Part written assignment, (under controlled conditions) and part investigative.	Written response to set theoretical tasks and written report to investigative work.
P4, P5	Hydrostatic Devices and Immersed Surfaces	Formal written assignment under controlled conditions.	Written answers to set tasks that cover the criteria.
P6, P7, M2, M3	Piped Measuring and Nozzle Vane Systems	Formal written assignment under controlled conditions, with appropriate test data being provided.	Written response to tasks, showing appropriate use of given data and related fluid flow theory.
P8, P9, M4, M5, D2	Determining Aerodynamic Parameters	Investigative assignment, part practical (subject to centre equipment limitations) part literature search.	Written report and observation record on the practical aspects of the assignment (as appropriate) plus written response to set theoretical tasks.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following units in the Engineering suite:

Level 1	Level 2	Level 3
	Applied Electrical and Mechanical Science for Engineering	Mechanical Principles and Applications
	Operation and Maintenance of Fluid Power Systems and Components	Principles and Applications of Thermodynamics

Achievement of the learning outcomes of this unit will contribute to the knowledge requirements of the Level 3 NVQ in Engineering Maintenance, Unit 19: Carrying Out Fault Diagnosis on Fluid Power Equipment and Circuits and Unit 20: Maintaining Fluid Power Equipment.

Essential resources

The following equipment is considered the essential minimum for the successful delivery of this unit:

- laboratory equipment for visualisation of adhesion forces and capillary action, such as calibrated test tubes and fluid in glass tube barometers
- Redwood viscometer or similar
- metered hydraulic bench with attachments for investigating differential pressure flow measurement and fully developed laminar flow in pipes.

Recommended resources

Although not essential, the following equipment is highly recommended to enhance learning and promote interest in the subject:

- additional attachments for hydraulic bench, including impact of a jet apparatus, plus the Venturi meter, orifice meter and Pitot-static tube flow measurement instruments
- open or closed section wind-tunnel, with appropriate measuring apparatus and models, such as manometers, digital velocity meters, lift and drag balance, Pitot-static head, aerofoil sections, model buildings/bluff bodies, model aircraft and motor vehicles
- hydraulic or pneumatic brake systems (rigs or on vehicles).

Employer engagement and vocational contexts

Opportunities should be sought to encourage companies involved with hydraulics, pneumatics, transport and civil engineering aspects of fluid power, to join the centre's unit and programme industrial focus committees. Having close contact with such companies opens up opportunities for learners to visit them, view or use equipment and arrange possible work placements.

There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Darbyshire A – *Mechanical Engineering BTEC National Option Units* (Elsevier, 2008) ISBN 075068657X

Douglas J, Gasiorek J and Swaffield J – *Fluid Mechanics* (Prentice Hall, 2006) ISBN 0131292935

Fox R, McDonald A and Pritchard P – *Introduction to Fluid Mechanics* (John Wiley and Sons, 2009) ISBN 9780470234501

Hannah J and Hillier M J – *Mechanical Engineering Science* (Prentice Hall, 2000) ISBN 0582326753

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are …
Independent enquirers	when determining the dynamic pressure exerted on a wind-tunnel model and determining its drag coefficient using theoretical data and/or using data from experimentation when investigating and evaluating the Venturi meter, orifice meters and Pitot-static tube and presenting report.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are …
Team workers	when using experimental methods, with team help, to investigate and evaluate fluid flow measuring instruments.

Functional Skills – Level 2

Skill	When learners are …
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	determining the surface coefficient for a given liquid on glass calculating viscous resistance and power loss in a lubricated plain journal bearing determining the output force and motion of a hydrostatic device determining thrust and flow velocities
Select and apply a range of skills to find solutions	determining the surface coefficient for a given liquid on glass calculating viscous resistance and power loss in a lubricated plain journal bearing determining the output force and motion of a hydrostatic device determining thrust and flow velocities
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the principles and applications of fluid mechanics
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explain how the viscosity of Newtonian fluids is affected by changes in temperature and pressure describing wind-tunnel equipment set-up.