



Unit 56: Industrial Robotics

Delivery guidance

In this unit, learners will explore the principles and operation of industrial robots used in modern manufacturing. They need to understand the health and safety implications of working with robots and the importance of maintenance schedules. They will use the knowledge and skills that they gain in this unit to develop programs to control robots to autonomously complete operations to solve engineering problems.

Learners need to recognise different control systems (such as electrical, mechanical, pneumatic and hydraulic) and the reasons for selecting them for different applications. They need to understand robot configurations, articulation, sensors and end effectors. Investigations into the operations and design of industrial robotics will lead to learners producing a case study on robotic installation and its design, operation and control.

Learners need to understand and be able to apply programming principles to generate a structured working program to carry out a realistic sequence of actions. They should demonstrate simulation, de-bugging and testing of the program in an incremental way.

Centres and assessors should be aware that learners must have access to a functioning robot, e.g. a six-axis jointed-arm in work cell or a linear robot using a Cartesian system. They will also need some form of industrial standard programming software, suitable for an industrial robot or work cell, e.g. RoboCell, KUKA.Sim, OrangeEdit or Microsoft Robotics Developer Studio.

Key areas of study include:

- considering safety and maintenance requirements
- the different operations and designs of industrial robots for different applications
- the operation and application of sensors and end effectors
- producing a program to solve an industrial problem.

Approaching the unit

It is essential that you allow learners to investigate the unit content in as hands-on a way as possible to link the theoretical concepts with practical experience. The unit provides many opportunities for learners to work with local industry, which will provide realistic scenarios in which learners can gain an understanding of the types of functions carried out by industrial robots and the environments in which they work.

If it is not possible to arrange a visit to a local company for learners to experience robots in the workplace, it may be worth considering whether companies could provide video clips or allow you to film activities for use in lessons. This could complement an industrial robotics facility at your Centre.

It may be possible for a large employer to provide support, such as staff members who can support learners carrying out technical activities (e.g. the development of their communication skills as part of a graduate apprenticeship).

Again, it is important to note that your centre needs to have sufficient facility for all learners to have access to the resources needed to carry out maintenance activities and develop programming skills. Learners need access to a functioning robot, such as a six-axis jointed-arm in work cell or a linear robot using a Cartesian system. Learners will also require industry-standard programming software. Please view the assignment briefs and associated assessment criteria in order to gather information about the expected learning outcomes.

Learning aim A

Health and safety is an important aspect of working with robots, but learners may have little experience of robots other than as toys or table top arms. Learners must be made aware of the potential dangers of industrial robots, while assuring them of their safe application and function parameters. An early planned visit to a local company could put the dangers and safety systems in context.

Learners should be conversant with the need for safety regulations and legislation. They should therefore accept the introduction of specific regulations, such as relevant Codes of Practice, and the range of relevant regulations that are appropriate to enable learners to understand the issues surrounding the health and safety and maintenance requirements associated with industrial robots.

The range of human factors associated with the successful completion of coding and maintenance should also be covered. Relevant information, such as faults when programming or system faults due to ineffective maintenance procedures, should be presented to learners to enable reflection and intervention as necessary. These discussions or relevant work completed by learners on the human dangers should lead onto the range of safety systems available as a preventative solution to the risks presented by human and autonomous dangers.

Although they are not specified directly in the unit content, you could introduce the need for risk assessments (linked to other units) and standard operating procedures. This could make it simpler for you to introduce maintenance routines and procedures. Ensure that all learners are able to carry out the maintenance exercises. This may require learners working in pairs or small groups and scheduling the access to each exercise appropriately, perhaps as a carousel. The maintenance activities provided should be sufficiently detailed and complex to provide learners with the familiarity of the spare parts required for maintaining robotic equipment and the tools and equipment required to perform the maintenance operations. Inspection routines and standard forms used either at the centre or on an industrial visit would be very useful to aid with the presentation of this topic. Give learners the opportunity to evaluate the overall effectiveness of the maintenance procedures upon completion.

Learning aim B

You may prefer to link the contents of learning aims B1 and B2 in a holistic way, as the design and principles of operation are directly connected. Inspection, disassembly, analysis and evaluation of robotic devices would be useful ways in which to present the topics found in this learning aim. An industrial visit, guest speaker(s) and/or video clips



could broaden learner experience of these topics. The same is true of the control systems required to operate autonomous systems.

Learners are more likely to have experience of mechanical and electrical drives, but probably less experience of pneumatics and hydraulics. You could include some simple experiments using plastic syringes to introduce the concepts involved. You could also use pneumatic/hydraulic test rigs, if available, to demonstrate control systems (e.g. controlling a double-acting cylinder). You could then move on to develop this to demonstrate a closed loop system in order to cover learning aim B3. For example, a pneumatic circuit pushes a component into position using a double-acting cylinder and then returns automatically. This concept could be developed to energise and cause an effector to pick up a component from a location and release it elsewhere.

Learners could investigate a range of engineering scenarios to exemplify content from learning aim B. Learners could study remote manufacturing technologies as well as remote surgery, to highlight some of the interface systems and control systems required for intricate procedures and processes.

Learning aim C

Learning aim C is closely linked to learning aim B: the final exercise described for learning aim B requires sensors to carry out the feedback function. You may choose to teach learning aims B and C holistically as the assessment model recommends a single assessment for both learning aims.

The concept of tool centre point (TCP) is needed to understand the concepts of world joint and tool reference frames in learning aim B2. Learners need to understand how tools and effectors are calibrated relative to a reference datum to provide accuracy and repeatability of movement. For example, the end effector for a pick-and-place operation needs to be positioned so that it can open around the target, close on it and pick it up every time. You could compare this with an arcade claw machine.

Learning aim D

It is important that learners have sufficient resources that they can access the integrated development environment (IDE) and work practically in pairs/small groups to carry out the testing requirements. There is a range of different integrated development environments available, such as RoboCell and KUKA.Sim. Please refer to the *Further information for teachers and assessors* section of the unit specification.

You could demonstrate a working program to learners (e.g. carrying out the example for learning aim B) and then go through the stages of development of the program and the use of an IDE. You could use a series of graduated exercises to help learners to develop skills in using the IDE. These exercises will teach learners how different functions work.

You could demonstrate how the sample program was developed from a design specification using typical programming stages. Learners could develop a similar program using the taught techniques and skills developed using the IDE. You may want to present a range of engineering briefs to the learners in order to differentiate the activities to target different abilities of learners.

You should base the scenario for the third assignment on a realistic industrial scenario, ensuring that it is not too complex for Level 3 learners. You might be able to gain ideas for projects from industrial partners. You may wish to invite representatives from industry and/or higher education institutions to participate in assessing learners'

presentations, ensuring that these representatives are aware of the requirements of a Level 3 learner. An effective way of doing this is to organise a showcase event, where learners set up their projects on stalls for visitors to view and to ask questions about, just as you might see exhibitors at a conference.

Assessment model

Learning aim	Key content areas	Assessment approach
A Investigate the health and safety and maintenance requirements associated with industrial robots	A1 Health and safety requirements A2 Maintenance	A report or presentation evaluating the safety systems and maintenance requirements in place for an industrial robot or robot work cell.
B Investigate the operation and design of industrial robots for different applications	B1 Principles of operation and their applications B2 Design principles B3 Control systems	A report of findings from research, evaluating an industrial robot installation in terms of its design, operation and control from a case study.
C Investigate the operation of industrial robot sensors and end effectors	C1 Sensors C2 End effectors	
D Produce a program for an industrial robot to solve an engineering problem	D1 Integrated development environment (IDE). D2 Programming principles and implementation	A program to control a robot that solves an engineering problem.

Assessment guidance

The unit specification states that you can use a maximum number of three summative assignments. As learning aims cannot be split across assignments, the recommendation is to structure assessment as in the table above.

It is important that you use the *Essential information for assessment decisions* (EIAD) in conjunction with the unit content and assessment criteria when making assessment judgements. The EIAD gives examples of how to interpret assessment evidence. Note that the degree of coverage does not appear in the assessment criteria but must be applied.

It is not required for learner evidence to include every item listed in the content. For example, not all the items listed in learning aim A1 (Safety systems) may be applicable to the robot system used in your centre, but there should be enough to meet the unit intention.

It is important that you closely monitor learner progress towards learning aim D to ensure that learners develop simple working solutions. It is possible for the most able learners to overthink their designs, which makes it difficult to complete them in time at a level to match learners' potential. Encourage learners to develop in a stepwise manner, so that optimisation is more evident.



Getting started

This provides you with a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 56: Industrial Robotics

Introduction

You could start by considering what a robot is and identifying key characteristics. Use a site visit or video clips to illustrate the range of industrial robot types and their applications.

Learning aim A: Investigate the health and safety and maintenance requirements associated with industrial robots

- Use a site visit or video clips to identify safety issues related to working with industrial robots. Use the videos to identify different types of robot and their applications. It is important that you identify the dangers to humans working with robots during programming, operation and maintenance.
- Make links to other units through the use of risk assessments and use this as way to introduce relevant regulations and legislation. You could use ideas from local industries to provide examples. For example, a visit host or guest speaker could indicate the safety systems in their workplace, explain the effectiveness of these systems and give examples of the company safety procedures. It is important that learners understand the need for safety systems and can relate them to industrial situations. Discuss the use of safety systems as control measures.
- Most industrial maintenance schedules use standard operating procedures (SOP). Learners may not have experience using SOP, so it could be worth including a lesson on them. A way to introduce the benefits of SOP is by carrying out a fun exercise, e.g. making a paper dart. Start with learners making their own design and have a flying competition. Discuss the degree of variability and the consequences for a manufacturing industry. Supply an SOP and repeat the construction and testing process. Review and edit the SOP with learners' suggestions. An interactive whiteboard is useful for this exercise.
- You could use simple mechanical systems to give learners the opportunity to follow a given SOP, use tools and replacement supplies and complete a standardised maintenance report form before assessment. For example, they could replace a drive belt on a pulley system, inspect a chain drive or lubricate a system. A carousel of short exercises would allow learners to experience a range of parts and tools. Discuss inspection routines and the listed factors, referring to learners' experience in the practical activity.
- You may be able to use industry resources to carry out the assessment of maintenance activities. For example, a large employer may have an apprenticeship training centre with sufficient resources. A further benefit would be the availability of risk assessments and an SOP. However, you may need to timetable access to your centre's robot system in order to allow all learners to complete a maintenance schedule, depending upon resources. Some learners could work on research and write reports while others carry out practical activities. It would be beneficial to have spare parts from robot systems for learners to dismantle, replace parts such as seals and rebuild using a range of tools. One activity could be to safely replace a pneumatic line, to introduce the dangers of stored energy.

Note: It would help learners to have access to summary notes for each topic in the unit specification, with spaces for them to complete in order to confirm their understanding and their ability to complete problems in the required manner. An example of how this was done in one centre was for the teacher to complete notes on an interactive whiteboard during the lesson and to then upload the pages on the virtual learning environment (VLE) for learners to access.

Learning aim B: Investigate the operation and design of industrial robots for different applications

Learning aim C: Investigate the operation of industrial robot sensors and end effectors

The recommended way to assess this unit is to link learning aims B and C. This means that it makes sense to teach the content of these learning aims in a holistic way.

- Introduce the variety of robot design by referring to a site visit and/or using video clips. Initially you could concentrate on design types, operational characteristics and specifications. You could illustrate the importance of each by using 'top trumps'-type cards, which will allow learners to become acquainted with robot features.
- Discuss the applications of industrial robots, their benefits and their potential negative aspects.
- You could then use video clips to consider the motive power (e.g. electrical, mechanical, pneumatic, hydraulic). Learners are more likely to have experience of electrical and mechanical drives, so you may decide to concentrate on pneumatic and hydraulic systems. Learners could carry out simple experiments to illustrate pneumatic and hydraulic principles.
- Introduce the concept of workspace organisation and relate it to safety considerations and dangers to humans (reinforce learning aim A1). One way of developing learners' understanding of workspace organisation would be for learners to carry out a 'game board' exercise, placing system components to meet a design specification. Potentially you could use industrial contacts to provide the scenarios based on their installations. You could also use photographs of the installations to compare with learners' designs.
- It could be beneficial to use a pneumatic/hydraulic rig to demonstrate control systems (e.g. control a double acting cylinder, then incorporate it into a feedback control system using limit switches to operate automatically). You could then demonstrate the relevance of this by operating a pneumatic end effector for a pick-and-place operation. Discuss factors such as automation and repeatability (reinforce learning aim A1).
- Use the ideas introduced by the pick-and-place exercise to introduce reference frames, articulation and singularities. You could include tool centre point (TCP) from learning aim C2 at this point.
- Use the videos again to identify sensors. Learners could identify sensors on the centre resources and carry out simple exercises using sensors, considering sensor applications and their function in safety systems. The availability of resources would probably require these to be carried out as a carousel.
- As part of carrying out practical exercises on simple pneumatic and hydraulic systems, learners should investigate manipulators and end effectors (either on a system or free-standing unit).



- Summarise types of robots, their applications and their impact (e.g. manufacturing, inspection, palletising, working alongside humans, replacing human workers).
- Ensure that learners have access to the robot systems to complete the requirements for these learning aims. Resources will probably dictate that learners work in groups to carry out practical activities. However, it is important to stress the need for learners to provide individual evidence.

Learning aim D: Produce a program for an industrial robot to solve an engineering problem

- It is probable that learners have some experience of programming, but not in the context of industrial robotics. You could start with the pick-and-place program and demonstrate how you can use the integrated development environment (IDE) to load the code, debug and simulate it.
- Demonstrate how to program the robot by the lead-through method, e.g. using a pendant.
- Develop the pick-and-place program, explaining the stages from a design specification, working through flow chart to structured English. Learners work in small groups to develop a similar pick-and-place program using the same techniques. Collate the solutions and develop an optimised solution.
- Use the optimised structured English solution to demonstrate how to write a program using the chosen IDE.
- Learners could use the IDE to simulate the program, debug and test incrementally once checked by the teacher for safety. Introduce the concept of stepwise testing and checking for conformation with the design specification.
- You need to allow time for learners to build up skills and confidence using the IDE. You could use a series of graduated exercises to introduce a range of commands. The exercises should include start-up, motion commands, work-cell commands, simulation and testing, editing and altering, operation.
- Discuss the advantages and disadvantages of different programming methods. The assignment should provide opportunities for learners to meet the assessment criteria and the *Essential information for assessment decisions* (EIAD). The problem to be solved should be industry-based, but not so complex that it cannot be solved in the available time. There is an opportunity for you to collaborate with local industry contacts in the design of the assessment. It would be beneficial if you could obtain industry support for this activity as noted above.
- You may find it difficult to arrange further opportunities for learners to access practical resources outside the time allocated to the unit. This is why it is important to make every effort to ensure that all learners complete practical exercises and obtain data at that time.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- Unit 36: Programmable Logic Controllers
- Unit 40: Computer Aided Manufacturing and Planning
- Unit 43: Manufacturing Computer Numerical Control Machining Processes.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Internationals in Engineering. Check the Pearson website at <http://qualifications.pearson.com/endorsed-resources> for more information as titles achieve endorsement.

Textbooks

Buckenham, A. et al, *Pearson BTEC National Engineering Student Book*, Pearson, 2016, ISBN: 9781292141008

The book was written to support the 2016 BTEC National Level 3 Engineering qualification, which has many similarities to this qualification.

Dinwiddie, K., *Basic Robotics*, Cengage Learning, 2016, ISBN: 9781133950196

The book walks readers step-by-step through the fundamentals of the industrial robot system.

Branwyn, G., *Absolute Beginner's Guide to Building Robots*, Que Publishing, 2003, ISBN: 9780789729712

Provides a basic guide to robotics and a list of recommended books.

Niku, S. B., *Introduction to Robotics: Analysis, Control, Applications* (Second Edition), Wiley, 2010, ISBN: 9780470604465

A comprehensive book set at university level, which is a good teacher resource.

Websites

Numerous websites cover the topics in the unit content. Selection is down to your personal delivery preference. However, you need to take care that the level is appropriate, as many resources are aimed at higher education courses.

Visit the Learnchannel-TV website, go to 'Overview' and select 'Robotics' for a bank of resources covering a wide range of topics related to industrial robotics, with a hyperlinked table of contents to simplify searching. You may need to provide more explanations, but it provides a good base.



There are many good examples of videos to select from on YouTube®, such as:

- the GalcoTV video entitled 'Industrial Robots have Transformed the Manufacturing Industry - A Galco TV Tech Tip', which provides a short introduction with a good range of types
- the CarTV video entitled 'Car Building Robots Production – KUKA Plant', which is quite long but shows the construction of a robot arm for the car industry
- the CarTV video entitled 'BMW plant Dingolfing – KUKA robots'
- the RoboticsStaubli video entitled 'Industrial robots for a palletizing application in the dairy industry', which shows the application of robotics in the dairy industry
- the Soft Robotics Inc. video entitled 'Soft Robotics – The Best Grippers for Industrial Applications'
- the SICK Sensor Intelligence video entitled 'Sensor solutions for robotics: Working together as equals', which shows examples of sensor systems
- the engineeringdotcom video entitled 'Robotic End Effectors Simplify Pneumatic Gripping and Robotic Sanding Applications', which shows footage of robot end effectors.

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