Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination 2017

Engineering

Chief Examiner's Report

Contents

1. Introduction

This Chief Examiner's report provides a review of the performance of candidates in the 2017 Leaving Certificate Engineering examinations. It provides an analysis of candidate achievement at both Higher and Ordinary levels for the three components assessed in Engineering: the technology project, the practical skills examination and the written examination. Tables of relevant statistical information are given in an appendix. The report should be read in conjunction with the examination papers, the published marking schemes and the syllabus for this subject. The examination papers and marking schemes are available on the State Examination Commission's website www.examinations.ie and the syllabus is available at www.curriculumonline.ie.

The present Leaving Certificate Engineering syllabus was first examined in 1985. Its stated *General Aims* are as follows:

> The course represents a study of a wide range of mechanical engineering materials, processes and technological applications integrated with the manipulative skills and techniques necessary for practical resourcefulness, creativity and design realisation in the execution of work.
>
> It aims to promote an educational knowledge of the materials; an understanding of the processes; ability in safely using the skills and tools to achieve objectives through practical work; initiative in the planning and development of technological projects.
>
> *Leaving Certificate Engineering Syllabus*

Students achieve these aims most effectively when they are encouraged to use their knowledge, skills and initiative, together with problem solving capacity and reflective thought, in the development of creative solutions to technology-driven design challenges. These aims also imply that the students will develop an understanding and appreciation of function, accuracy of work, and quality of finish, with a high regard for health and safety when using appropriate materials, processes, equipment and resources to develop and produce artefacts. They also need to develop strong verbal, written and graphic communication skills.

2. What does the examination test?

The examination at each level comprises three components, each of which plays a distinct and important role in assessing the extent to which candidates have achieved the aims of the syllabus:

2.1. Technology project

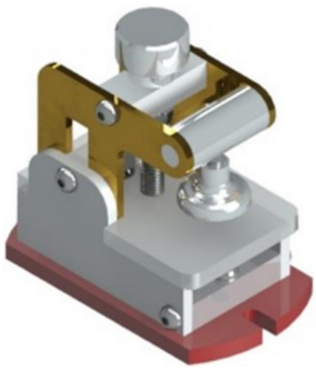
Candidates are required to submit a model and a design folio based on a design brief issued annually by the SEC. These briefs are designed to assess achievement of several of the primary aims of the syllabus, one of which is to 'to promote initiative in the planning and development of technological projects'. The project provides an opportunity for candidates to display their skills in creativity, problem solving, reflective thought and communication of design. It also facilitates the development of practical and precision skills by engagement with the syllabus content through a practically-based learning process and the use of a wide variety of engineering processes in a safe working environment.

The technology project has a mark allocation of 150 marks, which represents 25% of the total marks available at Higher level and 30% at Ordinary level. The 2017 brief at Higher level included specific design criteria and instructions for making a model '*search and rescue helicopter*' and compiling the design folio. At Ordinary level the 2017 brief had instructions to manufacture a model '*futuristic city car*' in accordance with the given diagram and compile a design folio. Candidates at both levels also have the option to manufacture the model based on their own 'alternative design', provided that the criteria outlined in the brief are adhered to.

2017 futuristic city car

2.2. Practical skills examination

The practical skills examination, which is assessed at a common level, has a mark allocation of 150 marks, which represents 25% of the total marks available at Higher level and 30% at Ordinary level. This examination, which is of six hours' duration (taken in two three-hour sessions), takes place in schools, under examination conditions, in early May. Lists of specific equipment and materials required for the examination are issued by the SEC to the schools, along with drawings and specifications for parts which each candidate is required to prepare prior to the examination. The practical skills examination assesses candidates' level of skill with regard to each of the following: interpreting a drawing, marking out, processing, finishing and assembling a test piece to a given specification. Candidates are required to demonstrate skills in precision filing, drilling, machining and fitting, using a good range of materials. A high level of accuracy is required for the test piece to function properly.



2017 test piece

2.3. Written examination

At Ordinary level, the written examination is of 2.5 hours' duration and is allocated 200 marks, which represents 40% of the overall mark allocation. The examination consists of seven questions, of which candidates are required to answer Question 1 and any three other questions from the remaining six. At Higher level, the written examination is of three hours' duration and is allocated 300 marks, which represents 50% of the overall mark allocation. The examination consists of a total of eight questions, of which candidates are required to answer Question 1 and any four other questions from the remaining seven.

At both levels candidates are required to demonstrate and communicate a knowledge of materials, understanding of processes, and technological applications. At Higher level, the examination also includes some mathematical applications and requires the ability to create and interpret graphs. The application of knowledge through analysis and evaluation of engineering processes and procedures is also assessed. Candidates are also afforded an opportunity to create a link with the design and practical experience gained during the technology project.

3. How well did the 2017 candidates achieve the objectives of the course, and how do we know?

While the syllabus does not include a detailed list of assessment objectives, the aims of the course, as cited in the introduction above, are clearly stated. In order to design assessments that faithfully reflect the syllabus aims and content, such a list of objectives can be inferred from those aims. Then, by ensuring that the tasks set in the various examination components focus on and cover these objectives, one can be confident that the performance of candidates in the examination as a whole can be relied upon as a measure of the degree to which they have achieved the intended aims. To this end, the Engineering examination is designed to focus on the extent to which candidates can:

- demonstrate knowledge and understanding of a wide range of engineering materials, mechanisms, processes and technological applications – respecting the associated safety requirements
- develop manipulative practical skills and cognitive skills in order to safely use appropriate materials, processes, equipment and resources to develop and produce artefacts
- integrate such knowledge and skills together with initiative, problem solving and creativity in the planning, design and development and realisation of technological projects, with due regard for issues of health and safety
- research and communicate technological information in written, graphical and mathematical forms and interpret, analyse and evaluate given data
- manufacture of simple operational mechanisms to a high standard of accuracy and quality of finish from working drawings involving interpretation, sequence of operations, safe execution of work and testing of the finished product
- demonstrate knowledge and understanding of the basic principles and applications of control technology, computer aided design and computer aided manufacture (Note: this objective applies as an explicit requirement only to candidates studying Engineering in the Leaving Certificate Vocational Programme, LCVP, and is assessed as an optional element in the written examination.)

The 2017 candidates' engagement with and achievement of the above objectives are considered in turn below. Commentary is based on an analysis of candidates' responses to specific questions or sections on the written examination at both levels and on the work submitted for the technology project and in the practical skills examination. Differentiation between the levels is achieved through differing levels of complexity of the tasks set in the examination paper, along with different performance criteria demanded in the associated marking schemes. The commentary below is based on feedback provided by examiners in their final reports and systematically collated by senior members of the examining team and the Chief Examiner.

3.1 Demonstrate knowledge and understanding of a wide range of engineering materials, mechanisms, processes and technological applications – respecting the associated safety requirements

Candidates at both levels were required to show knowledge and understanding of a range of engineering materials, mechanisms, processes and technological applications throughout the written examination. Candidates' level of achievement of this objective was also demonstrated in the design folio as part of the technology project. Question 1, Section A of the Higher level paper and Question 1, Sections A and B at Ordinary level are compulsory questions and are designed to assess content over a broad spectrum of the syllabus. Most candidates demonstrated good overall levels of achievement in both knowledge and in understanding. Responses in Question 1, Section A are expected to be brief, factual and insightful and many candidates achieved this, with some candidates using diagrams to good effect to aid answering. In this section many candidates displayed excellent awareness and understanding of technological developments and applications set in a modern context. Marks were occasionally lost due to insufficient clarity or detail in responses – for example in Higher level Question 1 (k), some candidates only described one of the gauges, in Question 1 (l), some candidates made excellent use of diagrams while many candidates produced vague answers showing a lack of understanding of the 'operation of a hydraulic ram'. In Question 1 (i) at Ordinary level, candidates were asked to describe the operating features of machines or mechanisms and were given images of these in the question. Many candidates used the given image to good effect, often redrawing and labelling it to give a detailed response. However, some candidates instead provided an application or use for the mechanism, failing to demonstrate any knowledge of the operating features.

Throughout the optional questions there were many opportunities to demonstrate attainment of this objective. In questions 2 to 8 at Higher level, candidates were often asked to use their knowledge and understanding to select a suitable material or process for a given technological application. For example, Question 5 (a) was as follows: '*The heavy steel pipe shown is first rolled into shape and is to be completed by welding. Part (i) Select a suitable automated welding process for joining the seams along the length of the heavy steel pipe. Justify your selection. Part (ii) Describe, with the aid of diagram(s), the main principles of operation for the selected welding process.*' In many responses to this question, suitable welding processes were identified and justified, with submerged arc welding, electro-slag welding and MIG the most popular suggestions for welding the pipes. Many candidates provided high quality detailed justifications and descriptions for the selected welding process, usually accompanied by labelled sketches. There was some reference by candidates to seam welding, which was not a suitable selection as it did not account for the heavy steel pipe or the context illustrated in the accompanying image. Furthermore, some candidates failed to provide any justification for their selection. There were also instances where proper and detailed labelling of diagrams would have enhanced candidates' responses.

Candidates demonstrated high levels of knowledge and understanding of mechanisms and awareness of their applications. This was evident in the variety of excellent responses to the turnstile mechanism problem set in the Question 8 (a) at Higher level and the responses to Question 1 (a), (i) and (m) at Ordinary level.

Candidates' ability to apply knowledge and understanding gained during the research, development and realisation of the technology project component was tested at both levels. Candidates' responses in this regard demonstrated a broad range of achievement, from weak to excellent. Many showed good initiative where the skills and knowledge acquired during the two-year Leaving Certificate programme, together with problem solving capacity and reflective thought, were integrated in the development of creative solutions to the technology driven design challenges they were presented with. This is a key set of skills in engineering and, when it is evident in candidates' work, it is a clear indication that they have achieved the intended aims of the syllabus.

Candidates demonstrated knowledge and understanding of a wide range of engineering mechanisms, processes and technological applications in the array of electrical control solutions used to operate the door, winch, and ramp in the Higher level project. These mostly consisted of a geared motor connected to a variety of mechanisms, the direction of movement being controlled by a DPDT switch, and speed variation where necessary by a potentiometer wired into the circuit. Many candidates may have overlooked the need to store and locate the required electronic components, batteries and wiring associated with electrical control solutions, with the result that limited space in the fuselage was often an issue. Where this issue was successfully resolved, the model was usually neat and compact, therefore scoring high marks. Some candidates manufactured a hand-held control panel, which circumvented this problem. Many of these were well executed and efficient, with a well-designed panel connected to the model via ribbon cable. Unfortunately, some others were connected via a series of individual wires, which were loose, untidy, and tended to become detached from the components to which they were connected.

3.2 Develop manipulative practical skills and cognitive skills in order to safely use appropriate materials, processes, equipment and resources to develop and produce artefacts

Many candidates demonstrated to good effect in both the technology project and the practical skills examination that they have acquired a high level of proficiency in manipulative practical skills. In many centres, these skills were clearly evident in the manufacture of well-designed models at both levels. High standards of accuracy and finish are continually stressed to be of great importance in producing a model and candidates' achievement of these was evident and is welcomed.

In many centres, a wide variety of bench and manufacturing skills were employed and standards ranged from fair to excellent. A vast array of engineering processes were used in models presented for examination. Many models displayed high levels of machining (CNC and manual lathe), excellent use of laser cutting technology, some evidence of 3D printing, very intricate folding and bending, drilling, milling, vacuum forming, a variety of joining techniques, electronics and pneumatics. Good modelling techniques were evident in many cases, especially at Higher level, and evidence from design folios demonstrated the contribution modelling made in the early stages of the design of the *search and rescue* helicopters. In specific centres, candidates also made good use of technologies such as circuit simulation software and CAD software to assist in modelling and prototyping possible solutions, as evidenced by the design folios presented. However, it was noted that the lack of final circuit diagrams prevented some candidates from attaining full marks. Candidates should be encouraged, where possible, to exploit the potential and capacity of using CAD software, such as *Solidworks*, early in the process, as it has immense potential as a design tool to aid the designer in developing, testing and making amendments to a design solution. Candidates who are proficient CAD users become well informed designers and can save significant time at many stages of the process.

Models which were well designed were generally assembled using a wide variety of well-executed, mechanical and thermal joining techniques, with appropriate use of screw threads, fasteners, thermal joining, and pop riveting. However, some examiners reported the over-use of adhesives in some instances. Proper execution of appropriate joining techniques and skills were essential for the smooth and efficient functioning of the model. Some excellent work was presented, especially in the joining of non-ferrous metals, where pop riveting, countersunk screws, nyloc and cap nuts were widely and appropriately used. These enhanced the final product. Candidates who completed the Junior Certificate Metalwork programme would have experienced these non-ferrous assembly techniques in the project and practical examinations at that level and it is welcome to see that experience drawn upon here. There were some cases of crude assembly, with the wheel or rotor not secured properly, incomplete electronic circuits, and gears not meshing correctly. The mechanical efficiency of some sliding doors and electric winches and hoists were compromised by poor assembly. Automation of the rear ramp proved challenging for many, and some candidates produced solutions to this design challenge that were poorly thought out. Completion and presentation of electronic circuits proved challenging for many candidates. This impacted on the functionality, safety and overall presentation of a finished model.

3.3 Integrate such knowledge and skills together with initiative, problem solving and creativity in the planning, design and development and realisation of technological projects, with due regard for issues of health and safety

As noted earlier, the project briefs are designed to, among other things, '*promote initiative in the planning and development of technological projects*'. In this context and in general, examiners reported favourably on the nature and the quality of the candidate's solutions to the given briefs. There was a wide-ranging display of design skills, often communicated well in the folio, coupled with excellent demonstrations of practical skills in the models produced. Many centres presented work with high levels of accuracy and finish in a wide range of uniquely designed project models, which were manufactured to very high standards using a wide variety of engineering processes. There were many examples where candidates demonstrated excellence in creativity, innovation, problem-solving and communication. In the realisation of the model, bench and manufacturing skills were executed to great effect with high levels of accuracy and finish inherent. Furthermore, many candidates took the opportunity to test and evaluate their own work, which is an important constituent of the design process. At Ordinary level, many candidates displayed a diversity of design skills, with some excellent designs and alternative designs, often represented well in the folio. There were some specific centres where Ordinary level candidates showed a high degree of engagement with the project, with many opting, very successfully, to design and manufacture their own alternative design. Such alternative designs gave scope to candidates to exercise their imagination and their creative skills, and some excellent work was presented.

The folio records the work of the candidate and should contain all the details of the design process from the initial ideas to the final evaluation. It should be developed in tandem with the model and should contain a complete contemporaneous record of work-in-progress. Candidates are given clear instructions in the design brief, under the heading Design Process, regarding the compilation of the folio. These are further reinforced in the marking scheme under '*Marking Criteria – Folio'*.

It is clear that the more successful candidates had read the Design Brief and the marking scheme in the examination paper carefully and followed the directions therein. They produced a concise design folio detailing all aspects of their work, often displaying excellence in both content and presentation. Teachers of such candidates are to be commended for the excellent guidance they had evidently given the candidates prior to and during this design process.

However, it must also be said that, even though in the minority, a significant percentage of models and folios were poor, and there were common errors and challenges. Skill levels varied between centres from excellent to poor. The level of finish and presentation of both the model and folio could be improved in many centres. Some candidates presented work which was poorly designed and, in some instances, poorly manufactured. Quality of finish will be dealt with in detail in the commentary on the next objective.

Some Ordinary-level candidates followed the format of the Higher-level folio. Candidates using this format did not satisfy the project brief and their work in some instances could not be adequately rewarded. Candidates at this level need to develop the design folio in tandem with the headings and instructions in section 2 of the Project Brief - *Planning and Organisation*, where candidates are *'required to compile a folio detailing the following aspects of your work'*.

There was a significant decrease in the percentage of the cohort submitting project work at Ordinary level compared to recent years. While the reasons for this cannot be stated definitively, it is reasonable to suggest that it may have been due to the change to the Leaving Certificate grading system and the associated change to entry criteria for higher education (the 'points system'). It is clear that some candidates opted for the Higher level project who might have been better served by choosing Ordinary level. Many such candidates did not score well, as the range of design and manufacturing skills required for Higher level is more demanding than those at Ordinary level. It was also noted that many of these candidates would have scored well at Ordinary level, where the emphasis is on a manufacture-orientated project brief. In other instances, candidates who had manufactured excellent models scored less well than they could have as they failed to submit a folio.

In some cases, candidates had clearly managed their time poorly, spending an excessive amount of time on manufacturing the model and devoting insufficient time to the folio. Such mismanagement of time can also impinge on the time available for studying for the written component of the examination. Project management needs to be addressed prior to and during the design process. Project management is crucial for a successful outcome, especially when constrained by time and by elements of the brief. It was evident from the folios of successful candidates that a structured process was implemented – from analysing the brief (brainstorming), to research and investigation, to mock up or modelling solutions, to selecting a final solution, to manufacturing the model using a work plan in conjunction with well-produced working drawings and testing and evaluating continuously throughout the process. The process of scheduling using a work breakdown structure, Gantt charts or critical path diagrams should be integrated into design folios. Some candidates would clearly have benefitted from more guidance in techniques for compiling such schedule plans for the manufacture of the model before project work commences.

There were many instances of poor marking out or no marking out, especially on complex components where successful assembly of the project was dependent on the accuracy of marking out and quality of manufacture of each component.

At higher level the section relating to the criteria for selection of solution proved challenging for some candidates. This is where the candidate presents a justification for the final solution selected. This requires higher-order thinking skills and is one of the areas where the candidate can demonstrate high achievement in the cognitive domain. It is evident that the higher-order skills of analysis, synthesis and evaluation proved challenging for some candidates who attempted the Higher-level project. The teachers' role is pivotal in developing these skills prior to the beginning of project work. Candidates who were successful presented valid reasons to justify the selection of their final design solution in order to satisfy the design brief. Some included a discussion based on an analysis of the merits of the selected final solution compared to the other possible solutions from the previous section in the folio, in terms of satisfying all criteria and specifications of the issued design brief. Some candidates tabulated a check list of categories including all criteria and specifications from the design brief. Other candidates were not able to display either the in-depth understanding or the analytic skills needed to justify and develop an appropriate final solution.

3.4 Research and communicate technological information in written, graphical and mathematical forms and interpret, analyse and evaluate given data

Many candidates demonstrated their attainment of the applied elements of this objective via the design folio in the technology project component. The quality of research and investigation has a significant influence on the overall quality of the model. Many candidates carried out extensive research with a clear focus and this guided them in the completion of the project. The best design solutions integrated research taken from the internet with primary sources of investigation. Weaker responses were dominated by the pasting of whole sections of material from the internet or other sources into their design folio with no attempt made to link this material to the development of the candidates' unique solution. Candidates must show evidence of analysis or reflective thought when engaging with such material.

The design folio is an excellent medium for candidates to demonstrate their communication skills. Candidates who were most successful used clear sketches, diagrams and a variety of modelling techniques to communicate and formulate their ideas, in order to arrive at a final solution. Modelling techniques, mentioned earlier in this report, can be a powerful medium to enhance the design process. They can include the use of CAD to simulate designs and the construction of 3D models using cardboard, straws and a variety of household and workshop materials. These techniques were used to good effect to determine what can or cannot be manufactured. This also gives an early indication regarding the size and proportion for the final design. All modelling is part of the design process. If any has been done, it should be presented with the final manufactured model and folio. All such models should be clearly identified with the candidate's examination number.

Candidates develop working drawings to communicate their final design ideas. The candidate should aim to provide a set of drawings and specifications which would allow a third party to produce their design. Some candidates delivered incomplete and poorly detailed drawings that lacked dimensions. Some candidates used CAD to great effect in this section, including both 2D and 3D presentations. An analysis of the full sample of folios shows that CAD, mainly SolidWorks, was used by a total of 699 candidates (14.9%) at Higher level but only ten candidates at Ordinary level (1.7%). While many centres show an improvement in the standard of draughting, some candidates produced drawings which were inaccurate, incomplete, poorly dimensioned and lacking in clarity. Circuit diagrams and mechanism details were frequently omitted in poorer responses.

The use of freehand sketches with effective labels and the inclusion of a small amount of colour would improve the quality of much work presented. In meeting this objective, the most successful responses provided a sequence of manufacturing, including digital images of the production processes involved in the making of the model. This section, in itself, provides an excellent verification of the steps taken to complete the project component.

At the start of the two-year programme candidates are issued with a prescribed topic. They have to research the topic and are assessed on this research in Question 1, Section B of the written examination. This is a compulsory question and is worth 50 marks overall.
The prescribed topic for 2017 was '*Principles and applications of robotic control in motor vehicle manufacture*'. The special research topic is an excellent means of rewarding student research and independent work, which is at the forefront of current industrial focus. Responses to this question highlighted that candidates had acquired a high level of knowledge and awareness of robotic control in the motor vehicle industry, with some providing an analysis into modern developments in this area. Some candidates were a little daunted by the depth of technical knowledge required.

Candidates at Higher level were asked to apply research carried out during the technology project in Question 8 (c), where they were shown a car suitable for wheelchair users and asked to '*Describe, with the aid of a diagram, a suitable mechanism to allow the sliding door to open.*' and '*Describe, with the aid of a diagram, a mechanism which will allow the ramp be automated.*' Many candidates successfully developed their responses based on the research and investigation they had carried out during the technology project, which had required them to design a sliding door and include an automated rear ramp in their model helicopter. Some candidates had developed good ideas but they were communicated in poor quality sketches with little significant labelling or detail.

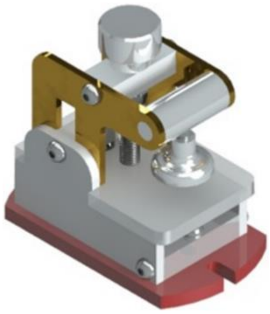
With regard to the ability to '*to interpret, analyse and evaluate given data*, many candidates struggle at the testing and evaluation stage of the design process. In many instances, the evaluation lacked depth and focus and was in the form of an overall conclusion, referring to time management difficulties and poor planning, often with an overemphasis on personal achievements rather than on obvious problems and associated solutions. Candidates who were most successful undertook a sustained reflection on the learning, drawing conclusions and developing insights in order to improve the process or enhance their design solution. Evaluation should be ongoing and is dependent on testing. In many cases, candidates did not carry out tests in accordance with the criteria specified in the project brief. Candidates should examine the results of various tests and come to a conclusion to see where the manufactured model is successful and in which areas there is room for improvement. These should be communicated in the 'Testing/Evaluation' section of the folio. The capacity to interpret, analyse, and evaluate given data is also tested in the written paper. Many candidates demonstrated good ability in converting tables of data into graphs as evident in Question 2 (b), 3 (b) and 4 (b) in the Higher level paper. However, some candidates had difficulties with the interpretation and application of numerical information and many candidates did not effectively or accurately determine the composition of the phases from the graph in Question 4 (b)(iii).

In assessing the folio, marks are allocated to its presentation. Many candidates were rewarded for the time and energy devoted to the development of this aspect of the folio. However, some candidates lost marks due to poor structure or lack of attention to detail. For some candidates, it seems evident that timely intervention and guidance from the teacher would have helped to bring the overall standard of the folio to the appropriate level.

An analysis of all projects marked at Ordinary level indicated that 29% of candidates failed to submit a folio (166 candidates). It was noted in the last Chief Examiner's report in this subject in 2011 that 28% of Ordinary level candidates had failed to submit a folio (268 candidates). At this level, before commencing the manufacture of the final solution, candidates must at least complete the following folio sections: planning details, alternative design details, parts list and working drawings. Some candidates, especially if using an alternative design or any variation on the given drawing, appeared to have difficulties engaging with the design process, understanding what is expected at each stage of the design process, and engaging with the concept of project management. It would have been beneficial to these candidates if teachers had taken specific time, prior to the issue of the design brief, to guide them through the design process as part of practical course work. An analysis of all projects marked at Higher level indicated that 10.2% of candidates failed to submit a folio. It was noted in the last Chief Examiner's report in this subject in 2011 that 8.7% of Higher level candidates had failed to submit a folio.

3.5 Manufacture of simple operational mechanisms to a high standard of accuracy and quality of finish from working drawings involving interpretation, sequence of operations, safe execution of work and testing of the finished product

The practical skills examination, which is taken at a common level, is the main means by which the achievement of this objective is assessed. The inherent levels of accuracy and precision required are unique to the practical examination, and this component therefore informs the majority of the commentary in this section. However, it must be stated that candidates' responses in the manufacture of the project models have also in many cases demonstrated very high levels of accuracy and precision. The Engineering practical skills examination consists of the following: interpreting a drawing, marking out, processing, finishing and assembling a test piece to a given specification according to the examination paper issued by the SEC. The practical skills examination of 2017 required candidates to produce a three-dimensional working model of a 'clamp mechanism' as shown opposite. The majority of candidates had little difficulty in interpreting the drawings provided, demonstrating an understanding of the inherent component and assembly detail.



This recognition and understanding undoubtedly contributed to the majority of candidates being capable of assembling the components in the correct manner. In more than 90% of centres, most candidates presented test-pieces which were assembled correctly with the mechanism functioning to different degrees of freedom.

Ensuring the full operation of the mechanism required a high degree of accuracy in marking out and manufacture, as it contained rotating and many sliding parts, all of which had to move in conjunction with one another in order for the mechanism to function correctly. It incorporated many self-testing features that pinpointed some inaccuracies in the candidates' work. The examination provided ample opportunity for candidates to demonstrate skills in precision filing, drilling, machining, fitting and accuracy, using a good range of materials. A high level of accuracy was required for the model to function properly and for candidates to therefore achieve a high score. While the examination allowed the high achievers to 'showcase' their skills, it also provided an opportunity for the weaker candidates to manufacture a reasonably functioning mechanism. However, some candidates found the accuracy and detail required challenging, resulting in some unfinished test-pieces.

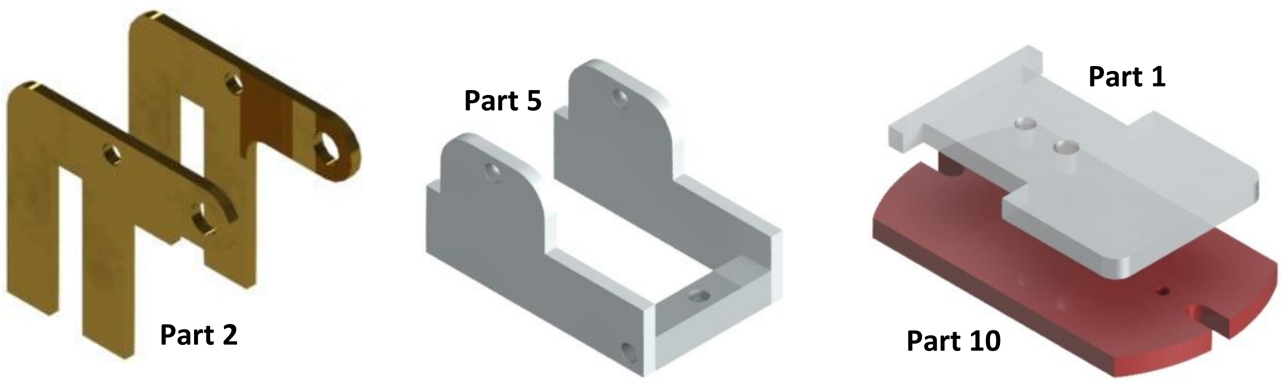
Candidates are advised to process the marking out of all the pieces as one sequence of operations and to check the marking out for accuracy prior to commencing the manufacture of the components. Teachers are advised to remind candidates of the importance of completing the marking out of all pieces prior to processing and of the significant mark allocation for completing the marking-out process, as shown in the published marking scheme. Candidates who were inaccurate with the marking out were often unable to assemble the test-piece.

The following are examples of some errors which occurred during the examination.

Candidates struggled to accurately shape semi-circles and quadrants on brass plates in Part 2 shown below. There were instances where candidates lost marks as a result of filing too far into rectangular slots.

The two side plates shown below, Part 5, were made from 4 mm aluminium. These pieces were a very good indicator of a candidates' ability to produce work to a high standard of accuracy and quality of finish. While many demonstrated high levels of proficiency, some candidates did not display the required level of skill to make the R10 mm quadrants or accurately manufacture the 5 mm step at the rear of each plate. Candidates who did not accurately locate the centres for the Ø5.5 mm holes had problems with the assembly and the functioning of the mechanism.

Parts 1 and 10 were made from polycarbonate and, surprisingly, these components proved significantly challenging for some candidates, who on average scored lower in this section than any of the other manufactured sections in this examination. Some candidates failed to accurately produce the 9 mm × 36 mm recesses in Part 1 and this affected the overall alignment of the mechanism. Some candidates failed to complete the slots to a high standard including a quality finish. The R50 mm curves on Part 10 were generally well filed with a smooth accurate curve produced. However, marks were lost by a small number of candidates who failed to recognise that this part was 100 mm long, not 104 mm as in the pre-prepared work. The failure to work from a single datum edge here cost some candidates marks, as this linear dimensional inaccuracy in the base had an impact on hole positions and thus caused assembly difficulties.



In this practical skills examination, high quality finishes on components may significantly improve efficiency in movement, the potential for accurate assembly, and the overall appearance of the test piece. Parts that have sliding contact with others may work better or last longer if the surface finish is of high quality. It is clearly stated on the examination paper that accuracy, finish and function are important elements in this examination and each are awarded a significant allocation of marks. High-achieving candidates produced work of quality with all the essential elements completed accurately, while still paying attention to details such as drawfiling cut edges, de-burring, and surface finishing of parts. Some candidates lost marks due to poor attention to the detail required to adequately finish components. In some specific centres, poor quality finish with little or no polishing was evident in all of the test-pieces presented for examination, suggesting that this matter had not been adequately dealt with in class. In such cases, failure to remove burrs, to drawfile or use emery paper to complete the components' edges caused many candidates to lose marks.

Quality of finish is not just an issue in the practical skills examination. In the technology project too, the importance of finish is highlighted in the brief: '*Marks are awarded for quality of presentation and finished appearance of both folio and model*'. As stated above, high-quality finishes on components may significantly improve efficiency in movement, the potential for accurate assembly, the aesthetic appearance of the component and the overall presentation of the complete model. There is also a significant allocation of marks awarded to finish and presentation of the folio and the model. Many candidates had clearly put a lot of effort into finishing, polishing and/or spray-painting parts before and after assembly. Generally, the standard of finishing was rather inconsistent – some candidates had produced high-quality finishes with immense attention to detail, but there were a number of instances where insufficient attention was given to this aspect of the manufacturing process. In some cases, high finishing standards were applied where components were made from acrylic, but this standard was not replicated on the components made from metal. Common errors included: poorly drilled and unfinished holes, excessive use of adhesive, protrusion of long machine screws, materials left in their raw state, electronic circuits left incomplete, unfinished, or loosely assembled.

Preparation of materials prior to the examination

Well in advance of the practical skills examination, the SEC issues instructions to teachers and directions to candidates regarding the equipment and materials required for this examination and regarding the preparation of materials prior to the examination. The accurate preparation of this material is essential to the functionality of the finished mechanism. In general, the preparation of materials was of a high standard, but some candidates lost marks due to poor dimensional accuracy in the prepared blanks. Also, in a number of test-pieces, examiners noted evidence of poor finishing and inaccuracies on machined components. In this regard, there was a distinct contrast between CNC-produced components and those completed on manual machines. The profile on Part 12 the 'clamping head' caused difficulties for candidates in a number of schools, particularly those without CNC lathes. The marks allocated for the materials prepared prior to this examination make up 20% of the marks allocated to this component. The importance of teacher supervision during this process is critical, as inaccurate blanks and poorly machined parts result in a significant loss of marks. Notwithstanding this observation, an analysis of the marks of all candidates indicates high levels of preparedness prior to the examination, as the average mark achieved in this section (16.6 out of 20) was the highest of the five sections detailed in the marking scheme.

3.6 Demonstrate knowledge and understanding of the basic principles and applications of control technology, computer aided design and computer aided manufacture (Note: this pertains to candidates studying Engineering in the Leaving Certificate Vocational Programme, LCVP, and is assessed as an optional element in the written examination.)

Some candidates demonstrated their attainment of this objective in the technology project (as evidenced in the design folio and in the model presented) and others in the practical skills examination (as evidenced by use of CNC technology in the preparing of pieces). The majority of candidates who used CAD did so to enhance the development of the technology project. This was clearly demonstrated in their folios, especially during the 'investigation of solutions' stage and in the production of final working drawings. As stated earlier in the report, some candidates also made good use of CAD software to assist in modelling and prototyping possible solutions as evidenced by the design folios presented. It would be extremely helpful to candidates if greater emphasis was placed on design intent and economy of design.

A number of candidates experimented with different elements of control technology in the project. Some candidates used PIC controllers to good effect, as these small, programmable electronic devices allowed them to add intelligence to their project designs. However, it was noted that the lack of final circuit diagrams and flowcharts for PIC control applications prevented some candidates from attaining full marks.

Laser-cutting technology, if used correctly, can also enhance the manufacturing process. Parts manufactured using laser, CNC or other CAM technologies should have production CAD drawings presented in the folio.

Candidates also demonstrated their attainment of this objective through the written examination, where questions on pneumatics, robotics, 3D printing and CNC technology were popular options and, in the majority of cases, elicited responses demonstrating good levels of awareness and understanding of the principles and applications of these technologies.

4. What can current and future students and their teachers learn from this?

The above observations lead to the following advice for students.

During the learning:

- Note that your teachers' experience and knowledge are invaluable. Consequently, you should consult with your teacher and heed his or her advice when selecting appropriate levels and approaches to the technology project and the practical skills examination.
- Develop a broad knowledge and understanding of a wide range of engineering materials, mechanisms, processes and technological applications.
- Develop and practice manipulative practical skills over the years of study leading to the examination.

- Gain maximum exposure in a practical setting to developing manufacturing skills using a range of appropriate materials, processes, equipment and resources.
- Integrate such knowledge and skills together with initiative, problem solving and creativity in the planning, design and development of a range of models and artefacts.
- Have a good knowledge and awareness of issues relating to health and safety.
- Take frequent opportunities to engage with design challenges over the years of study leading to the examination; use each such opportunity to research a technology-based project and communicate this technological information to classmates and/or your teacher through discussion, presentation, or in a design folio.
- Develop an appreciation for and strive to demonstrate high standards of accuracy and quality of finish during the manufacture of simple operational mechanisms based on the interpretation of working drawings.
- Develop a knowledge and understanding of the basic principles and applications of control technology, computer-aided design and computer-aided manufacture.
- Exploit the potential and capacity of using CAD software, such as *Solidworks*, early in the process, as it has immense potential as a design tool to aid the designer in developing, testing and making amendments to a design solution.
- Practice freehand sketching and drawing line diagrams, and be aware of the importance and effectiveness of well-proportioned labelled diagrams and sketches in supporting responses in both the written examination and the design folio.
- Be familiar with the requirements, instructions and the terminology used in the Engineering syllabus, past examination papers and marking schemes.

While doing the technology project:

- Take the opportunity to integrate knowledge and skills together with initiative, problem solving and creativity in the planning, design and development of design folios and manufacture of models using a wide variety of engineering processes and resources.
- Address project-management techniques prior to commencing the technology project in order to set appropriate targets and make optimal use of the time spent on project work.
- Ensure the design folio is completed in accordance with the headings and instructions outlined in the Project Brief section of the examination paper.
- The design folio should be developed in tandem with the model and should contain a complete contemporary record of work-in-progress, recording all the work and containing all the details of the design process from the initial ideas to the final evaluation.
- Pay particular attention to the finishing of the individual components that make up the model and folio, as well as the overall finish and presentation of each. Be aware of the

importance of finish and presentation and of the significant quantity of marks allocated to each.

- Evaluation and reflection, along with the communication of these, should be ongoing with regard to each design challenge. Develop testing techniques in accordance with the criteria specified in the project brief.
- Where possible, use CAD software, such as *Solidworks*, early in the process, as it has immense potential as a design tool to aid the designer in developing, modelling, testing and making amendments to a design solution.
- Design folios will be further enhanced if particular attention is placed on producing well-proportioned, labelled and shaded sketches, producing accurate and well-dimensioned working drawings, producing the relevant circuit diagrams, and producing CAD diagrams if CAM is used to manufacture a specific component.
- Integrate ICT into the folio using digital media to record the on-going development of the model.
- For Ordinary level design folios: show clear evidence if planning or developing an alternative design; put dimensions on working drawings; show evidence of materials used and of finishing techniques used during manufacture.
- Complete all technology project coursework in school under the direct supervision of your teacher and according to the instructions issued by the State Examinations Commission. If you do not, your teacher cannot authenticate the work and the SEC will not be able to accept it. This is to ensure the integrity of the coursework being assessed and upholds the principle of fairness for all, by ensuring that everyone is subject to the same conditions. The SEC policy and practice for the acceptance of practical coursework for assessment are outlined in Circulars S68/04 and S69/04. Copies of these circulars are available on the SEC website www.examinations.ie.

During the practical skills examination

Students:

- Take the opportunity to display your skills in precision filing, drilling, machining, fitting and accuracy, using a good range of materials.
- Process the marking out of all the pieces as one sequence of operations and check the marking out for accuracy before you start manufacturing the components. Be aware of the significant mark allocation for completing the marking-out process.
- Always strive for high-quality finishes on components, as this may significantly improve efficiency in movement, the potential for accurate assembly, and the overall appearance of the test piece. Parts that have sliding contact with others may work better or last longer if the surface finish is of high quality.
- Note that it is clearly stated on the examination paper that accuracy, finish and function are important elements in this examination and each is allocated a significant number of marks.

- Note that the accurate preparation of materials, as described in the instructions issued by the SEC prior to this examination, is essential to the functionality of the finished mechanism and this work is awarded a significant allocation of marks.
- Use the full six-hour time allocation available for the examination. For example, on completing the assembly and functioning of the test-piece, any remaining time could be used for final finishing and polishing.
- Do not use any machinery other than that specified in the equipment list to process any part of the examination material. If you do, you will lose marks under the relevant headings in the marking scheme.

Teachers:

- Please ensure that each candidate is given a copy of paper M74A(ML2), 'Directions to candidates'.
- Please ensure that the preparation of materials by each candidate prior to the Practical Examination is part of the examination process and that this preparation by candidates is their own individual work.

Prior to and during the written examination:

- Make sure that you are familiar with past written examination papers, marking schemes and sample solutions, which are available on the SEC website: www.examinations.ie.
- Continue to develop and practice examination technique, using sample solutions to practise and become familiar with the required techniques and terminology associated with the written examination.
- Make sure you attempt the required number of questions.
- Read the full examination paper at the start of the examination, before attempting any questions, and use the full allocation of time for the examination.
- Make sure you understand the meaning of the 'command words' used on the examination paper. For example, take the time to provide detailed answers in response to question cues such as 'describe' or 'explain', which require more development than instructions like 'state' or 'outline'.
- Note that responses in Question 1, Section A are expected to be brief, factual and insightful. Use diagrams to help where appropriate.
- Answer all parts of the attempted questions. No marks can be awarded for a particular part if that part is not attempted.
- Use freehand sketching and drawing line diagrams when possible to support answering, and be aware of the importance and effectiveness of well-proportioned labelled diagrams/sketches to support responses in the written examination.

Final note of thanks

The SEC acknowledges and thanks Engineering teachers and school authorities for their assistance in: ensuring the integrity of coursework projects submitted for assessment; preparing and laying out centres for marking the projects; and preparing for and ensuring the smooth running of the practical skills examination.

Appendix: statistics & trends

Participation trends

Year	*Engineering* candidature	Total Leaving Certificate candidature*	*Engineering* as % of total
2013	4881	52772	9.23
2014	5203	54025	9.63
2015	5376	55047	9.77
2016	5379	55707	9.66
2017	5275	55770	9.46

*Total Leaving Certificate candidature excludes Leaving Certificate Applied candidates.

Table 1: participation in Leaving Certificate ***Engineering***, 2013 to 2017

Year	Total *Engineering* candidature	Number at Ordinary Level	Number at Higher Level	% Ordinary Level	% Higher Level
2013	4881	1139	3742	23.33	76.67
2014	5203	1031	4172	19.82	80.18
2015	5376	968	4408	18.01	81.99
2016	5379	890	4489	16.55	83.45
2017	5275	689	4586	13.06	86.94

Table 2: number and percentage of candidates at each Level, 2013 to 2017

Year	Total Higher Level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2013	3742	156	3586	4.2	95.8
2014	4172	203	3969	4.9	95.1
2015	4408	249	4159	5.7	94.3
2016	4489	219	4270	4.9	95.1
2017	4586	264	4322	5.8	94.2

Table 3: gender composition of Higher Level ***Engineering*** cohort, 2013 to 2017

Year	Total Ordinary Level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2013	1139	77	1062	6.8	93.2
2014	1031	73	958	7.0	93.0
2015	968	75	893	7.8	92.2
2016	890	79	811	8.9	91.1
2017	689	51	638	7.4	92.6

Table 4: gender composition of Ordinary Level ***Engineering*** cohort, 2013 to 2017

Overall performance of candidates

The grading scale for Leaving Certificate examinations changed in 2017. Direct comparison with all aspects of the grade distributions from previous years is not possible. Nevertheless, data from 2016 and 2015 are presented in as comparable a way as is possible. The column widths in tables 5 to 10 below reflect the widths of the corresponding grade bands, so that the boundaries between these columns are aligned according to the corresponding grade boundaries. For example, the layout reflects the fact that grade 6 in 2017 is directly comparable with grades D2 and D3 combined in 2016 and 2015, but grade 7 in 2017 is not directly comparable to any grade band(s) from 2016 and 2015.

Year	Total	1	2	3	4	5	6	7	8
2017	4586	4.6	17.0	23.4	22.1	19.9	9.5	2.9	0.6

		A1	A2 + B1	B2 + B3	C1 + C2	C3 + D1	D2 + D3	E	F	NG
2016	4489	4.2	17.2	24.7	24.2	17.8	9.4	2.2	0.2	0.0
2015	4408	2.8	16.1	25.9	25.7	18.6	8.7	2.0	0.2	0.0

Table 5 Percentage of candidates awarded each grade in ***Engineering*** at Higher Level, 2017, with comparative data from 2016 and 2015

Year	Total	1	2	3	4	5	6	7	8
2017	264	4.2	18.9	21.2	20.5	22	11	1.9	0.4

		A1	A2 + B1	B2 + B3	C1 + C2	C3 + D1	D2 + D3	E	F	NG
2016	219	3.7	18.7	25.1	23.3	16.9	10.5	1.8	0.0	0.0
2015	249	2.4	14.8	26.5	23.3	15.6	12.8	3.2	1.2	0.0

Table 6 Percentage of female candidates awarded each grade in ***Engineering*** at Higher Level, 2017, with comparative data from 2016 and 2015

Year	Total	1	2	3	4	5	6	7	8
2017	4159	4.6	16.9	23.5	22.2	19.8	9.4	3.0	0.6

		A1	A2 + B1	B2 + B3	C1 + C2	C3 + D1	D2 + D3	E	F	NG
2016	4270	4.2	17.1	24.7	24.3	17.9	9.3	2.2	0.3	0.0
2015	4322	2.8	16.2	25.9	25.8	18.7	8.4	1.9	0.2	0.0

Table 7 Percentage of male candidates awarded each grade in ***Engineering*** at Higher Level, 2017, with comparative data from 2016 and 2015

Year	Total	1	2	3	4	5	6	7	8
2017	689	0.6	5.7	16.1	26.6	24.2	16.5	7.5	2.8

		A1	A2 + B1	B2 + B3	C1 + C2	C3 + D1	D2 + D3	E	F	NG
2016	890	0.1	5.2	17.8	24.2	22.9	18.7	8.7	2.2	0.3
2015	968	0.6	8.3	21.1	27.3	22.4	14.8	4.4	1.0	0.0

Table 8 Percentage of candidates awarded each grade in ***Engineering*** at Ordinary Level, 2017, with comparative data from 2016 and 2015

Year	Total	1	2	3	4	5	6	7	8
2017	51	0.0	13.7	9.8	33.3	23.5	17.6	2.0	0.0

		A1	A2 + B1	B2 + B3	C1 + C2	C3 + D1	D2 + D3	E	F	NG
2016	79	0.0	8.9	14.0	32.9	21.6	11.4	6.3	5.1	0.0
2015	75	0.0	10.6	18.7	30.7	22.6	10.7	5.3	1.3	0.0

Table 9 Percentage of female candidates awarded each grade in ***Engineering*** at Ordinary Level, 2017, with comparative data from 2016 and 2015

Year	Total	1	2	3	4	5	6	7	8	
2017	638	0.6	5.0	16.6	26.0	24.3	16.5	8.0	3.0	
		A1	A2 + B1	B2 + B3	C1 + C2	C3 + D1	D2 + D3	E	F	NG
2016	811	0.1	4.8	18.1	23.3	23.1	19.4	8.9	2.0	0.4
2015	893	0.7	8.1	21.4	26.9	22.4	15.1	4.4	1.0	0.0

Table 10 Percentage of male candidates awarded each grade in ***Engineering*** at Ordinary Level, 2017, with comparative data from 2016 and 2015

Engagement with and performance on individual questions

The data in tables 11 and 12 are based on an analysis of a random selection of scripts.

Question	Popularity (% attempts)	Rank order in popularity	Average mark, out of question total (and as %)	Rank order in average mark	Topic
1	99.9	compulsory	72.4 (72.4%)	compulsory	General Knowledge
2	79.4	2	30.9 (61.8%)	3	Testing of Materials
3	44.6	6	23.1 (46.2%)	7	Ferrous Metals
4	46.9	5	26.0 (52.0%)	6	Non-Ferrous Metals
5	83.4	1	32.2 (64.4%)	1	Joining Techniques
6	49.6	4	29.3 (58.6%)	5	Polymers
7	43.1	7	30.2 (60.4%)	4	Machining
8	64.4	3	31.1 (62.2%)	2	Mechanisms

Table 11: popularity of and average mark for each question, Higher Level ***Engineering***

Question	Popularity (% attempts)	Rank order in popularity	Average mark, out of question total (and as %)	Rank order in average mark	Topic
1	100	Compulsory	41.8 (41.8%)	Compulsory	General Knowledge
2	61	3	20.2 (40.4%)	4	Metal Production
3	69	2	18.5 (37.0%)	6	Heat Treatment
4	55	4	18.9 (37.8%)	5	Joining Techniques
5	52	5	22.7 (45.4%)	2	Plastics
6	75	1	25.6 (51.2%)	1	Machining
7	51	6	21.1 (42.2%)	3	Metrology

Table 12: popularity of and average mark for each question, Ordinary Level ***Engineering***

Section	Average mark out of 20	Topic
1	13.7	Assembly, function and finish (of all parts)
2	15.0	Parts 2
3	15.2	Parts 5 and 9
4	14.9	Parts 1 and 10
5	16.6	Parts 3, 4, 6, 7, 8, 11 and 12

Note: the total mark awarded out of 100 is multiplied by 1.5 to yield the final mark out of 150.

Table 13: average mark for each section in practical skills examination, ***Engineering***