SFEU

Scottish Further Education Unit

Skills for Work:
Engineering Skills Intermediate 2

Mechanical and Fabrication

Support Material

June 2008

Scotland's Colleges

Acknowledgements

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Scottish Further Education Unit (SFEU)
Argyll Court
Castle Business Park
Stirling
FK9 4TY

website: www.sfeu.ac.uk
e-mail: sfeu@sfeu.ac.uk

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Engineering Skills: Mechanical & Fabrication (Intermediate 2)
F39B 11

Introduction

These notes are provided to support teachers and lecturers presenting the Scottish Qualifications Authority Unit F39B 11*, Engineering Skills: Mechanical & Fabrication (Intermediate 2)*.

Enquiries relating to this support pack or issues relating to copyright should be addressed to:

Marketing Officer - Communications
The Scottish Further Education Unit
Argyll Court
Castle Business Park
Stirling
FK9 4TY

Website: www.sfeu.ac.uk

Further information regarding this Unit including Unit Specifications, National Assessment Bank materials, Centre Approval and certification can be obtained from:

The Scottish Qualifications Authority
Optima Building
58 Robertson Street
Glasgow
G2 8DQ

Website: www.sqa.org.uk

Class Sets

Class sets of this pack may be purchased direct from the printer. Costs are dependent on the size of the pack and the number of copies. Please contact:

Elanders Hindson
Merlin Way
New York Business Park
North Tyneside
NE27 0QG

Tel: 0191 280 0400
e-mail: info@elandershindson.co.uk

Disclaimer

Whilst every effort has been made to ensure the accuracy of this support pack, teachers and lecturers should satisfy themselves that the information passed to candidates is accurate and in accordance with the current SQA arrangements documents. SFEU will accept no responsibility for any consequences deriving either directly or indirectly from the use of this pack.

Contents

How to Use this Pack

None of the material in this pack is mandatory. Rather, it is intended as a guide and an aid to delivery of the Unit. It aims to provide centres with a flexible set of materials and activities which can be selected, adapted and used in whatever way suits individual circumstances. It may also be a useful supplement to tried and tested materials and approaches that you have developed yourself. The pack is available on the SFEU website in Word format to enable you to customise it to your suit your own needs.

The **Reference Section** of the pack provides information on:

- the rationale for, and ethos behind, the *Skills for Work* courses
- the Course Rationale
- the Unit Outcomes and evidence requirements
- the Employability Skills Profile for Intermediate 2 Engineering, showing where the specified employability skills and attitudes can be evidenced and assessed throughout the Course and in the Mechanical & Fabrication unit.

The **Tutor Support Section** contains:

- advice on learning and teaching with under-16s
- guidance for tutors on delivery of the Unit, including a scheme of work and a series of suggested lesson plans
- suggested resources
- advice on Health and Safety considerations
- guidance on integrating the development of employability skills throughout the unit.

The **Student Support Section** contains:

- a range of student activities covering the practical outcomes of the Unit
- detailed notes covering the knowledge and understanding aspects of the Unit
- a glossary of terms used in mechanical engineering.

You may wish to place material from the student notes on your own college Intranet by downloading this pack from the Skills for Work section of the SFEU website www.sfeu.ac.uk/skills_for_work

Activities are identified with the symbol: 

Reference Section

What are Skills for Work Courses all about?

Skills for Work Courses are designed to help candidates to develop:

- skills and knowledge in a broad vocational area
- Core Skills
- an understanding of the workplace
- positive attitudes to learning
- skills and attitudes for employability.

A key feature of these Courses is the emphasis on **experiential learning**. This means learning through practical experience and learning by reflecting on experience.

Learning through practical experience

Teaching/learning programmes should include some or all of the following:

- learning in real or simulated workplace settings
- learning through role play activities in vocational contexts
- carrying out case study work
- planning and carrying out practical tasks and assignments.

Learning through reflecting at all stages of the experience

Teaching/learning programmes should include some or all of the following:

- preparing and planning for the experience
- taking stock throughout the experience - reviewing and adapting as necessary
- reflecting after the activity has been completed - evaluating and identifying learning points.

The *Skills for Work* Courses are also designed to provide candidates with opportunities for developing **Core Skills** and enhancing skills and attitudes for **employability**.

Core Skills

The five Core Skills are:

- Communication
- Numeracy
- Information Technology
- Problem Solving
- Working with Others

Employability

The skills and attitudes for employability, including self-employment, are outlined below:

- **generic skills/attitudes valued by employers**
    - understanding of the workplace and the employee's responsibilities, for example time-keeping, appearance, customer care
    - self-evaluation skills
    - positive attitude to learning
    - flexible approaches to solving problems
    - adaptability and positive attitude to change
    - confidence to set goals, reflect and learn from experience.
- **specific vocational skills/knowledge**
    - Course Specifications highlight the links to National Occupational Standards in the vocational area and identify progression opportunities

Opportunities for developing these skills and attitudes are highlighted in each of the Course and Unit Specifications. These opportunities include giving young people direct access to workplace experiences or, through partnership arrangements, providing different learning environments and experiences which simulate aspects of the workplace. These experiences might include visits, visiting speakers, role play and other practical activities.

A Curriculum for Excellence (Scottish Executive 2004) identifies aspirations for every young person. These are that they should become:

- successful learners
- confident individuals
- responsible citizens
- effective contributors.

The learning environments, the focus on experiential learning and the opportunities to develop employability and Core Skills in these Courses contribute to meeting these aspirations.

The Course in Engineering Skills (Intermediate 2)

Course Rationale

The Engineering Skills (Intermediate 2) Course has been designed to provide a basis for progression into further education or for moving directly into training in employment within an engineering sector. The overall purpose of the Course is to ensure that candidates start to develop the generic and practical skills, knowledge and understanding, and employability skills needed within an engineering sector.

The engineering sector includes the following:

Mechanical	Manufacture	Maintenance
Fabrication	Welding	Electrical
Electronic	Foundry	Automotive
Control	Transport	Aeronautical
Communications	Space	Energy Generation
Conservation	Marine	Water
Desalination	Oil/Gas	Petroleum

This Course focuses on the broad areas of Mechanical, Fabrication, Electrical, Electronic, Maintenance, Manufacture, and an element of Design. This will allow the candidates to gain transferable skills which can be applied to any of the above engineering areas.

The primary target group for this Course is school candidates in S3 and above. It may be suitable for candidates entering engineering for the first time but also for those who have completed the Engineering Skills (Intermediate 1) Course. This Course will build on the skills and knowledge developed in the Engineering Skills (Intermediate 1) Course and will introduce candidates to a wider range of engineering applications.

It is anticipated that, for this group of candidates, the Course will rely on and build on existing partnerships between schools and colleges and employers (or other agencies). This may be particularly pertinent in the case of the Engineering Skills Course due to the specialist expertise and facilities available in, for example, further education colleges and training providers. Nevertheless, the Engineering Skills Course is designed at a level and scope such that it can be delivered in schools, if the school has suitable facilities and teaching expertise. A partnership approach would still be necessary in order to provide the contact with the workplace which is an essential part of the experience for candidates. The Course is also suitable for adult candidates who are seeking to enhance their employability and develop introductory vocational skills in an engineering sector.

The general aims of the Engineering Skills (Intermediate 2) Course are to:

- widen participation in vocationally-related learning for school candidates from S3 upwards
- allow candidates to experience vocationally-related learning
- provide candidates with a broad introduction to the engineering vocational sector
- encourage candidates to foster a good work ethic, including timekeeping, a positive attitude, and other relevant employability skills
- provide opportunities to develop a range of Core Skills in a vocational context
- encourage candidates to take charge of their own learning and development
- provide a range of teaching, learning, and assessment styles to motivate candidates to achieve their full potential
- facilitate progression to further education and/or training
- encourage candidates to plan their work and review their progress
- encourage candidates to develop a positive attitude to waste minimisation and environmental issues

In particular, the aims of the Engineering Skills (Intermediate 2) Course are to:

- encourage candidates to consider a career in the engineering industry
- develop an awareness of what opportunities there may be within engineering in terms of the types and range of career options
- enable candidates to develop and apply practical, technical, and communication skills as a foundation for future learning and progression
- develop the candidates' awareness of their individual strengths and weaknesses in relation to the requirements of engineering, and to reflect on how this affects their employability potential
- give candidates the technical knowledge, skills, and understanding associated with a range of skills in engineering at this level
- give candidates an introduction to the design cycle
- encourage candidates to apply their knowledge and understanding of engineering by using skills of evaluation and problem solving in a vocational context
- develop an awareness that health and safety issues are integral to the world of work generally and engineering in particular
- prepare candidates for further learning opportunities, study, and training for employment in engineering and related occupations

The Engineering Skills (Intermediate 2) Course has been designed with National Occupational Standards in mind. The standards set for first-year apprentices in the engineering industry, and the standards set out in the Intermediate 2 Course, are broadly comparable in terms of skills and tolerances.

While no formal entrance qualifications are required for this Course, it would be expected that candidates embarking on the Course would have the following:

- basic proficiency in literacy
- basic proficiency in numeracy
- some aptitude for graphical forms of communication (the reading of basic engineering drawings is developed in the Course)
- motivation to work as part of a team

This Course supports progression into appropriate further education, training, or employment. The Course provides the basis for candidates to gain an insight into engineering occupations such as Mechanical, Fabrication, Automotive, Aeronautical, Electrical, and Electronic, Marine, Control, Maintenance, and Manufacture and to use their studies to help them decide the career they wish to follow. Candidates studying this Course in Engineering and choosing a skills option, may be aiming to progress into an apprenticeship in industry. Candidates who are uncertain which trade to follow may undertake vocational courses at further education colleges.

The Intermediate 2 Course should facilitate progression to a relevant vocational Course or an appropriate National Certificate/Qualification programme.

Unit Outcomes, PCs and Evidence Requirements

National Unit Specification: statement of standards

Unit: Engineering Skills: Mechanical and Fabrication (Intermediate 2)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit Specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Identify and use tools to measure and mark selected engineering materials.

Performance Criteria

a) identify engineering materials and state a reason for use
b) identify a range of measurement tools correctly and clearly state their function
c) mark out work pieces accurately from drawings and material specifications
d) complete a quality check to ensure marked dimensions are within specified tolerances
e) correctly observe safe working practices in all practical activities.

Outcome 2

Identify, select, and use a range of metal working tools

Performance Criteria

a) identify a range of metal working tools correctly and clearly state their function
b) select and use a range of metal working tools correctly for given tasks
c) correctly observe safe working practices in all practical activities

Outcome 3

Manufacture an artefact from given drawings.

Performance Criteria

a) produce an artefact from given working drawings and material specifications
b) functional dimensions of the artefact are within specified tolerances
c) the quality and finish of the completed artefact complies with the specification

d) correctly observe safe working practices in all practical activities

e) complete a quality check on own finished artefact

Outcome 4

Review and evaluate own employability skills in practical engineering contexts.

Performance Criteria

a) review and evaluate own employability skills

b) seek and record feedback on own performance in employability skills

c) make a judgement on own strengths, weaknesses and learning points in relation to employability skills

d) identify action points for improvement in relation to employability skills

Evidence Requirements for the Unit

Performance and written/oral evidence is required to show that all Outcomes and Performance Criteria have been achieved.

Performance evidence will be supported by assessor checklists. This evidence will be generated from an integrated assignment consisting of practical activities carried out in supervised workshop conditions.

The evidence may be gathered at different points throughout the Unit.

The practical activities in the preparation, planning and manufacture of an artefact in a safe manner will cover:

- Identification, selection and a reason for use of each of the following engineering materials:
  low carbon steel
  copper
  stainless steel
  aluminium
  non metallic

- Interpretation of engineering drawings and specifications.

- Selection, function and use of the following tools to measure and mark out: rule, scriber, square, dividers, calliper, protractor, micrometer and any one digital instrument.

- Selection and use of the following tools to cut and shape:
  hammer, chisel, hacksaw, tin snips, shears, files, drills and taps

- Selection and use of the following tools to form:
  heat source, anvil, vice, formers, hammers, mallets, stakes, rolls and folders

- Selection and use of the following methods to join:
  riveting (pop or solid); bolting, screwing; MIG/MAG welding; adhesives (any recognised engineering adhesive).

The artefact(s) will be completed:

- Using any material(s)
- Using any 6 measuring and marking tools
- Using any 4 cutting and shaping tools
- Using any 3 forming tools
- Using any 2 joining methods

Dimensions must be within the stated tolerance of ± 1mm, as expressed in the National Assessment Bank (NAB) material.

Candidates will be required to carry out a quality check before submitting their work for final assessment.

Written/Oral Evidence

Candidates will complete a self evaluation review of their own performance against the following employability skills:

- Maintaining good timekeeping and attendance
- showing health and safety awareness — to include wearing Personal Protective Equipment (PPE), safe working practices, and understanding a basic risk assessment
- selecting and using engineering tools and materials – source and use tools in a correct and safe manner; use tools solely for the purpose for which they are designed and selection of engineering materials
- quality checking own work
- self review and evaluation — to include identifying strengths and weaknesses, identifying learning points from practical experiences and having a positive attitude to learning

A signed record of the review must be retained by the assessor as assessment evidence.

The National Assessment Bank (NAB) item for this Unit provides an appropriate practical assignment, an appropriate candidate review sheet and assessor checklists. These exemplify the national standard. Centres wishing to develop their own assessments should refer to the NAB to ensure a comparable standard.

NB Centres must refer to the full Unit Specification for detailed information related to this Unit.

Employability Skills Profile

In addition to the specific, vocational skills developed and assessed in this Course, employability skills are addressed as detailed in the table below. For the purposes of the table, the Units are referred to as A, B, C and D as indicated.

Engineering Skills (Intermediate 2)

Mechanical and Fabrication	**=**	**A**
Electrical and Electronic	**=**	**B**
Maintenance	**=**	**C**
Design and Manufacture	**=**	**D**

Employability skills/attitude	Evidence
• maintaining good timekeeping and attendance	A, B
• showing health and safety awareness	A, B, C, D
• selecting and using engineering tools and materials	A, B
• interpreting engineering drawings and specifications	B, C, D
• working cooperatively with others	C, D
• planning and preparing for work	C, D
• applying time management	D
• awareness of environmental considerations	B, C
• quality checking own work	A, B, C, D
• self review and evaluation	A, B, C, D

Assessment evidence in all Units:

Assessor observation checklists of practical activities and candidate review sheets.

Careers Scotland Support

for School/College Collaboration for Scotland's Colleges in the Scottish Enterprise area

Since August 2006 Careers Scotland (SE and HI areas) has been funded by the Scottish Government to support College/School Collaboration and encourage and promote vocational educational choices for pupils in schools.

Careers Scotland (now part of Skills Development Scotland) has an important role to play in selection, recruitment and pre-entry career guidance, as well as ongoing support and pre-exit career guidance, to ensure the pupils' experience of SfW is capitalised upon in any future career planning.

Careers Scotland activity takes place locally and nationally under 4 objectives:

- Providing careers advice, guidance and employability support to pupils and their parents pre, during and post vocational education experience, focusing primarily but not exclusively on SfW pupils - demonstrating how these educational choices have implications for future career options, and support the achievement of future career goals and supporting effective transitions
- Providing targeted support to pupils at risk of becoming unemployed who would benefit from undertaking a vocational course
- Partnership working to ensure vocational study is given parity of esteem with other school and post school options, focusing on recruitment / selection and retention of pupils on vocational courses
- Capacity building through relevant shared CPD events and resource development to increase understanding of the process of uptake of vocational options and facilitate more effective support to pupils navigating these options

For further information on Careers Scotland (SE)'s involvement in school/college collaboration locally, please get in touch with your Careers Scotland Regional contact:

South East (Edinburgh & Lothians; Forth Valley; Borders)
Stephen Benwell 01786 452043 stephen.benwell@careers-scotland.org.uk

North East (Tayside; Grampian; Fife)
Val Ormiston 01592-631155 valerie.ormiston@careers-scotland.org.uk

South West (Dumfries & Galloway; Ayrshire; Lanarkshire)
Jean Geddes 01698 742192 jean.geddes@careers-scotland.org.uk

West (Glasgow; Dunbartonshire; Renfrewshire)
Sandra Cheyne 0141 242 8338 sandra.cheyne@careers-scotland.org.uk

Tutor Support Section

Introduction

The main purpose of this Unit is to enable students to select and use the basic tools and materials associated with mechanical and fabrication engineering at an introductory level, leading to various practical activities and the manufacture of an artefact. During the manufacture, students will read simple engineering drawings, measure and mark, select appropriate materials and work to specified tolerances.

Students will learn terminology and skills during the process of the practical work. They will also develop work practices and attitudes that will enhance their employability skills.

The need to promote safe working practices in the engineering workshop with respect to industry is paramount at all times.

Safe working practices should include:

- keeping the workplace tidy and free from obstruction
- maintaining good working relationships with others
- maintaining a positive attitude to instruction
- using tools for their intended use only
- using tools correctly
- being appropriately dressed for workshop activities
- wearing the relevant Personal Protective Equipment (PPE)

In addition to being taught the correct techniques for handling and using tools and materials, students should be given support in all aspects of the practical activities and employability skills.

The time allocations for each Outcome are intended as a guide only. The actual time spent on each Outcome will depend on the ability and prior experience of the student.

The Outcomes in this Unit are practical and students should be given ample opportunity to handle and work with tools and equipment relevant to mechanical engineering and fabrication. Building student confidence is a vital and important part of the unit, therefore students should be given adequate support in all stages of practical work.

Extension Activities

There is a substantial degree of similarity between the Intermediate 1 Engineering Skills: Mechanical and Fabrication Units and this Intermediate 2 Unit.

This means that the student handouts and elements of the activities in this support pack are similar to those of the Intermediate 1 support pack. This is necessary for use with students who have not progressed through the Intermediate 1 route although the outputs will need to be demonstrated at a higher skill level.

Learning and Teaching with Under 16s

Scotland's Colleges have made significant progress in meeting the needs of young learners. Our knowledge of the learning process has increased significantly and provides a range of strategies and approaches which gives us a clear steer on how lecturers can add to their skill repertoire. Lecturers can, and do, provide a stable learning environment where young students develop a sense of self-respect, learn from appropriate role models and see an opportunity to progress. There are basic enabling skills for practical application which can further develop the learning process for this group of students. So what are the characteristics of effective learning and teaching which will help to engage young learners?

Ten ways to improve the learning process for under 16s
(This list is not exhaustive!)

1. **Activate prior knowledge and learning** – ascertain what the learner knows already and teach accordingly. Young people do have life experience but it is more limited than adult learners and they may not always be aware of how it will assist them in their current learning.

   Tips - Question and answer; Quick Quiz; Quick diagnostic assessment on computer; present key words from the course or unit and see how many they recognise or know something about.

2. **Tune learners into the Big Picture** – the tutor knows the curriculum inside out and why each lesson follows a sequence, however the young learner does not have this information and is re-assured by being given the Big Picture.

   Tips – Mind map or concept map; use visuals, for example wall displays of diagrams, photographs, flow charts; explain the learning outcomes in language they will understand; We Are Learning Today (WALT) targets and What I'm Looking For (WILF) targets; give clear and visible success criteria for tasks.

3. **Use Advance Organisers** – these are lists of the key concept words that are part of the course or unit.

   Tip – Highlight on any text the concept words that you will be using; make a visible list and put it on display – concept words can be struck off or referred to as they occur (NB this helps with spelling and independent learning as they do not have to keep checking meaning); highlight essential learning and action points.

4. **Vary the teaching approaches**. The two main approaches are instructing and demonstrating, however try to provide opportunities to facilitate learning.

   Tips – Ask students what they know now that they did not know before, or what they can do now they could not do before, at appropriate points in the lesson or teaching block; ensure there are problem solving activities that can

be done individually or in groups; ask students to demonstrate what they have learned; use a range of question and answer techniques that allow participation and dialogue, eg. provide hints and cues so that they can arrive at answers themselves.

5. **Preview and review of learning**. This helps to embed previous learning and listening skills and provides another opportunity to elicit learner understanding. Consolidates and reinforces learning.

   Tips – At the beginning of each lesson, or session, review previous learning and preview what is coming up; at the end of each lesson or session, review what has taken place and what will be focussed on next time – these can both be done through question and answer, quizzes and mind mapping activities.

6. **Language in the learning environment**. Do not assume that the language which is used in the learning environment is always understood by young learners, some words may be familiar but do not have the same meaning when used vocationally.

   Tips - At appropriate points ask students what words mean; explore the various meanings of words to find out if they may have come across this language in another context; by looking at the structure and meaning of words there is an opportunity for dialogue about learning and to build vocabulary.

7. **Giving instructions in the learning environment**. This is one of the most difficult tasks a tutor has to do whatever the curriculum area. With young learners this may have to be repeated several times.

   Tips – Ask a student to repeat back what you have asked them to do before beginning a task; ask them to explain the task to one of their peers; use the KISS principle – Keep It Short and Simple so that they can absorb and process the information.

8. **Effective feedback**. Feedback is very important for the learner to assess their progress and to see how and what they can improve. Provide opportunities to engage in dialogue about the learning function of assessment – provide details of the learner's strengths and development needs either in written or spoken form. With younger learners identifying one or two areas for development is sufficient along with acknowledgement of what has been done well.

   Essentially, learners are helped by being given a **specific** explanation of how work can be improved. You can also use summative assessment formatively, ie. as an opportunity to identify strengths, development needs and how to improve.

   Tips – Ask students themselves to identify their own strengths and development needs – self evaluation; peer evaluation of work can be successful once they have been taught how to do it; the tutor can produce a piece of work and ask students to assess it anonymously; have a discussion about the success criteria for the task and ensure the students are clear about

them; allow learners to set criteria for success and then measure their achievements against these.

9. **Managing the learning behaviour**. Under 16s are coming into Scotland's Colleges and training establishments from largely structured and routine-driven environments in schools and early feedback from those undertaking Skills for Work courses indicates that they very much enjoy the different learning environment that colleges and other training providers offer. Remember though that these are still young learners. They will still expect tutors to provide structure and routine, and will perform best in a calm, orderly learning environment. Young students will respond to firm, fair, and consistent management. Such routines have to be established quickly and constantly reinforced.

   Tips - Health and safety is non-negotiable and consequences of non-compliance with the regulations should be made clear and adhered to at all times; set out your expectations from day one and provide a consistent message; have clear beginnings, middles and endings for each session; be a positive role model for your students, ie. be there before they are and manage the learners with respect; always deliver what you promise; build up good relationships and get to know the learners, make the curriculum interesting and stress the relevance of the learning; set up a positive behaviour management system. By following these guidelines you will build up two-way respect, which, while sometimes challenging to achieve, can be very powerful and work to everyone's benefit.

10. **Care and welfare issues**. School/college partnerships mean increasing numbers of young learners in college. Tutors have to be aware of their professional responsibilities and mindful of young people's rights. However tutors have rights too, in terms of feeling safe and secure in working with young people and there are basic steps staff can take to minimise risks. It is essential that colleges ensure that tutors have a working knowledge of the Child Protection policies (local authority and college documentation) and follow procedures and policies diligently. School/College Liaison Officers will be familiar with these documents and can provide support and advice. There are also training sessions on Child Protection available from SFEU (see the following page).

    Tips - Avoid one-to-one situations with young students in a closed area; do not do or say anything that could be misinterpreted; if the opportunity arises, do some observation in schools to see and discuss how teachers use the guidelines for their own protection as well as the young person's.

Most young people are a delight to work with and they will positively enjoy the experience of learning in college. However, there will inevitably be some who are disengaged, disaffected and who have not yet had an opportunity to experience success. '*Skills for Work*' is a unique educational initiative that young people can be motivated to buy into – you as the tutor are key to the success of these programmes.

Skills for Work Workshops

To take this 10 point plan forward and to add to it, you can attend one of SFEU's *'Get Skilled Up'* half day workshops for tutors delivering *Skills for Work* Courses, when we explore further the learning process and look at a range of specific teaching and learning techniques to use with the under 16 age group. To find out when the next event is visit our website www.sfeu.ac.uk or contact the Learning Process team at SFEU on 01786 892000.

Child Protection Workshops

These are run on a regular basis by staff at SFEU in Stirling and also in colleges. For more information on these workshops please contact members of the Access and Inclusion team at www.sfeu.ac.uk or contact the team at SFEU on 01786 892000.

General Guidance on Unit Delivery

The emphasis in this unit is on a practical approach in which the students complete practical tasks and activities. The unit is also designed to focus on the employability skills that employers value.

The Unit should be delivered in a workshop environment with students being appropriately dressed. Health and Safety should be emphasised at the start and finish of each practical activity. Students should wear overalls, safety footwear and other PPE (Personal Protective Equipment) as required in the workshop. They should be made aware that employability skills such as attendance, punctuality, working with others, seeking advice and reviewing their progress will also be developed, supported and monitored. It is important that students evaluate their progress with employability skills and at the same time start to evaluate their practical skill development and state what they were good at and what they were not so good at in both areas.

As students progress through the practical activities, it is envisaged that opportunities will arise to discuss employability skills development and perhaps subsequent career paths. There should be adequate time to progress mechanical and fabrication engineering skills whilst at the same time giving each student a good insight to engineering both locally and nationally.

Associated knowledge and skills to be developed include:

- names and use of tools
- safe workshop practice
- comprehension of information from simple drawings
- commonly used terminology.

The Unit could be integrated for delivery with other units of the course and if this is the case this support pack should be used in conjunction with that of other units.

The unit is also an ideal opportunity to progress Core Skills within the context of Mechanical and Fabrication:

Numeracy Skills: in the form of measuring and cutting material.

Working with Others: is a valid and inherent skill in any workplace or workshop, and students should be actively encouraged to seek advice from their tutor and work with their peers as part of a team.

Problem Solving: engineering is beset with problems and trades people are faced on a daily basis with problems that require efficient and cost effective solutions.

Communication: part and parcel of the engineer's working life is communication, whether it be taking in oral or written instructions, interpretation of drawings, interpretation of manufacturers' manuals, making an oral presentation or simply giving instructions to others.

IT: is linked to all of the above. Most engineers use IT to aid numeracy skills, to communicate and to problem solve. IT is widely used to present and record information and to provide graphic communication for engineers. The Internet is a valuable resource to enable students to seek additional information about tools and processes.

Unit Induction

Although the Unit will have been outlined at the course induction it is vitally important to include an induction to the Unit. The students need to know what exactly the unit is about, what they will accomplish and achieve and, just as important, what is expected of them. The overall practical aspect of the course and unit will need to be reinforced. It should be stressed at unit induction that the skills valued by employers such as timekeeping, attendance etc will be monitored and recorded and that all students will be encouraged to show a positive attitude. The short time spent on Unit induction will pay dividends later in the Unit.

Unit induction can start with some practical work - students will want to get stuck into the fun part as soon as they possibly can. Then to keep up their enthusiasm, the following should be introduced:

- an outline of the Unit content – what they're going to be doing
- how it fits in to the *Engineering Skills* Course
- your plans for teaching the Unit – how they'll be learning the practical skills
- assessment methods and schedule
- where employability fits in – start by asking them what they think!
- a section on health and safety
- a practical mechanical and/or fabrication activity
- the importance of regular attendance and good timekeeping to encourage employability skills development - get them into good habits just as if they were at work and in employment!
- you might also think about inviting an engineer or engineering apprentice from a local firm to speak to the class about their work, about job prospects in the engineering industry and to reinforce the value that employers put on employability skills.

Health and Safety - Note

Students need to understand their roles and responsibilities in relation to health and safety. Students may already have an appreciation of health and safety issues in one of the other course units but it should be emphasised to them that in this unit they may be dealing with a different set of potential hazards and that each practical activity will probably start and end with health and safety issues relevant to the practical skills covered in the lesson.

Scheme of Work

In the Mechanical and Fabrication Unit students will learn to select and use the correct tools, equipment and materials required to manufacture an artefact(s) from a diagram or given specification. Students will also develop and use engineering skills including measuring, marking, cutting, shaping, drilling and tapping, forming and joining.

At the beginning and throughout each Outcome of the Unit the following should be emphasised and adhered to:

Safe Working Practices in the Workshop	**The Care and Use of PPE**
• Workshop Safe Working Practices • Workshop Housekeeping • Health and Safety • Accident Procedures • Fire Alarm Procedures	• footwear • overalls • eye protection • hand protection

The first three Outcomes should be taught in order with Outcome 4 integrated throughout all the practical activities.

Outcome 1 (approximately 5 hours)

Identify and use tools to measure and mark selected engineering materials

Identify engineering materials and state a reason for use	• low carbon steel • copper • stainless steel • aluminium • non metallic • mechanical properties of materials • reasons for use such as corrosion resistance, non-magnetic, lightweight, strong
Mark out pieces accurately from drawings and material specifications	• engineering drawings • specifications

Complete a quality check to ensure marked dimensions are within specified tolerances	• drawing interpretation • dimensions • quality check
Correctly observe safe working practices in all practical activities	• appropriate aspects of current Health and Safety legislation • COSHH (Control of Substances Hazardous to Health) Regulations • systems of work relevant to the workshop/workplace

Outcome 2 (approximately 15 hours)

Identify, select and use a range of metal working tools

Identify a range of metal working tools correctly and clearly state their function Select and use a range of metal working tools correctly for given tasks	• hammer • chisel • hacksaw • tin snips • shears • files • drills and taps • heat source • anvil • vice • formers • hammers • mallets • stakes • rolls • folders • riveting (pop and solid) • bolting • screwing • MIG/MAG welding • adhesives

Correctly observe safe working practices in all practical activities	• appropriate aspects of current Health and Safety legislation • COSHH (Control of Substances Hazardous to Health) Regulations • systems of work relevant to the workshop/workplace

Outcome 3 (approximately 15 hours)

Manufacture an artefact from given drawings

Produce an artefact from given working drawings and material specifications.	• drawing interpretation • material selection • cutting • shaping • forming • joining
Functional dimensions of the artefact are within specified tolerances.	• drawing interpretation • general tolerance • length • breadth • height
The quality and finish of the completed artefact complies with the specification.	• drawing interpretation • dimensions • finish • quality check
Safe working practices are correctly observed in all activities.	• appropriate aspects of current Health and Safety legislation • COSHH (Control of Substances Hazardous to Health) Regulations • systems of work relevant to the workshop/workplace
Complete a quality check on own finished artefact	• drawing interpretation • dimensions • finish • quality check

Outcome 4 (approximately 5 hours)

Review and evaluate own employability skills in practical engineering contexts.

Review and evaluate own employability skills. Seek and record feedback on own performance in employability skills. Make a judgement on own strengths, weaknesses and learning points in relation to employability skills. Identify action points for improvement in relation to employability skills.	Demonstrate specific employability skills correctly and complete a Review Sheet covering: • maintaining good timekeeping and attendance • showing health and safety awareness • selecting and using engineering tools and materials • quality checking own work • self review and evaluation.

Health and Safety Considerations

General safety in the workplace

This deals with the issues of:

- General Health and Safety
- Personal Protective Equipment (PPE)
- Safe working techniques (including tool-handling)
- First Aid
- Fire Alarm
- COSHH
- Good housekeeping in the working environment
- Manual handling

Each student will require the minimum **PPE** of safety boots and overalls for most workshop activities. In some cases students may require additional equipment such as goggles, gloves, safety spectacles or ear defenders.

Safe working techniques will include general workshop behaviour and protocol. This will include the correct handling and transportation of tools; tool safety; workshop layout; and procedures for starting and finishing practical activities.

First Aid considerations should include awareness of the nearest first aid station, first aider, first aid procedures, accident and 'near miss' reporting, and avoidance of potential accidents.

Fire Alarm evacuation procedures should be practised and students made familiar with the audible warning sound, alarm points, location of fire fighting equipment, fire exits, assembly areas and correct conduct under alarm conditions.

The **Control of Substances Hazardous to Health** (COSHH) must be stressed if students are subjected or exposed to any chemicals, fumes, dust or irritants.

Good housekeeping is the welfare of all participants and the general working conditions in the workplace. This will include safety, PPE, behaviour, conduct, storage and condition of tools and equipment, walkways and handling and disposal of waste oil and scrap materials.

Whilst the tasks may not always require the movement or handling of heavy objects, the use of safety footwear and manual handling techniques should be discussed and encouraged as a matter of good safety practice. Some tasks may require using heat or a heat source and students should be made aware of the dangers of both hot and previously heated materials and workbenches.

Personal Safety

The students need to appreciate that they are responsible for their own safety and the safety of others. This will include their conduct and behaviour in all activities. Safe working practices in workshops and the safe use of tools and equipment should be emphasised.

In all the activities students are asked to perform they should be encouraged to make sound judgements on issues such as:

- the effect of their actions on fellow students
- are the tools and equipment in good usable condition?
- are they being asked to carry out an action they are unfamiliar with?
- should they seek advice from an appropriate person?

Students' personal dress should be hardwearing and give protection against grease/oil/heat etc. This clothing should not have any loose sleeves.

Students should be dissuaded from wearing sports trousers and tops as these items are nearly always manufactured from plastic materials and are not suitable for engineering workshop use.

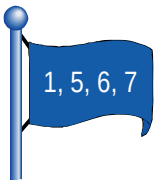
No jewellery of any form should be worn and neither should any piercings be worn.

Further information on Health and Safety can be found in the SFEU Publication '*Engineering Skills: Course Guidance and Employability Skills Intermediate 2*.

Signposting of Employability Skills

In addition to the specific vocational skills developed in this Unit, students will have opportunities to develop and apply their knowledge and understanding of the employability skills.

Throughout the pack there are numbered flags, like the one shown here, showing which specific employability skill can be highlighted and/or assessment evidence recorded when students are busy with the various activities in the Unit.



1	Maintaining good timekeeping and attendance*	6	Planning and preparing for work
2	Showing health and safety awareness*	7	Applying time management
3	Selecting and using engineering tools and materials*	8	Awareness of environmental considerations
4	Interpreting engineering drawings and specifications	9	Quality checking own work*
5	Working cooperatively with others	10	Self review and evaluation*

The employability skills marked with an asterisk* are directly assessed in this Unit.

Guidance on Integrating Employability Skills

The Unit is designed to give the students the technical knowledge, skills and understanding associated with a range of skills in fabrication at this level but at the same time it should help the students to develop an awareness of what opportunities there may be within engineering in terms of the types and range of career paths and options.

It is anticipated that the development and recording of employability skills will be ongoing throughout each practical unit. It should be stressed at unit induction that that skills valued by employers such as timekeeping, attendance etc will be monitored and recorded and that all students will be encouraged to show a positive attitude. Tutors should look for every opportunity to teach about the value of developing good employability skills whilst also teaching trade specific skills.

Generating Evidence and Assessment Opportunities for Employability Skills

The unit is designed around practical assignments which should enable the students to develop and apply practical, technical and communication skills as a foundation for future learning and progression. As instances arise naturally within the completion of practical assignments, job roles and career paths may be discussed so that all students are aware of progressions within the engineering sector. These discussions will also encourage an interest in engineering in general.

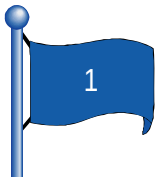
It is important in that the students develop the ability to reflect on how they performed in the completion of tasks. In the context of this Mechanical and Fabrication unit this will involve reflection on the development of both practical and employability skills. The skill of evaluation lets the students analyse what they did well, what they did not do so well and how they can improve. This means they will develop an awareness of their individual strengths and weaknesses.

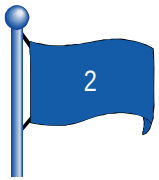
The unit also encourages the students to apply new found knowledge and understanding of engineering in the completion of practical assignments by using skills of evaluation and problem-solving in a vocational context.

The following employability skills will be assessed in this unit. However, please note that it is expected that all the other employability skills are also developed throughout the unit.

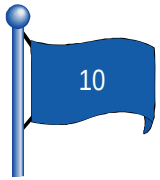
- maintaining good timekeeping and attendance
- showing health and safety awareness – to include wearing PPE, safe working practices and understanding a basic risk assessment
- selecting and using engineering tools and materials – source and use tools in a correct and safe manner, use tools solely for the purpose for which they are designed and selection of engineering materials
- quality checking own work
- self review and evaluation – to include identifying strengths and weaknesses, identifying learning points from practical experiences and having a positive attitude to learning

You will find and create countless opportunities to help students develop their employability skills. Some ways of going about it to get you thinking are given in the next pages and are also in the **SFEU Publication '*Engineering Skills: Course Guidance and Employability Skills Intermediate 2*.**

Employability Skills	Delivery Advice	Possible Activities/Contexts
 **Timekeeping and attendance**	• Make your expectations clear right from the start of the course or Unit. A good initial activity is to have the students write the class guidelines themselves by identifying pros and cons of good and poor attendance and timekeeping – the benefits in the workplace of one and the consequences of the other. These guidelines or ground rules can be posted in the workplace and referred to on a day to day basis. • Relate your ground rules to the world of work, eg. arrive on time, back from breaks on time etc. The measure of a student's success in this aspect is for them to be honest in their appraisal of their performance and in making progress. 'Distance travelled' should be adopted, rather than a particular minimum percentage of classes attended. Attendance and timekeeping should be monitored throughout the Course and Units. Students should be given feedback on their performance – both good and bad – in this regard. If you take note of patterns in performance it should be easy to give the students accurate feedback.	• turning up for class • returning from breaks • sticking to planned work schedules regarding timing of activities • staying in class for the duration of the planned activity (no extended toilet breaks)

 **Showing health and safety awareness**	• Health and Safety is very important to employers and is a key part of the learning and teaching of each Unit from the first workshop session to the last and so there should be ample opportunity to collect evidence of health and safety issues. • Safe Working Practices • A basic Risk Assessment • Identification of hazards by students • First Aid and Fire awareness. • Discussion on what PPE might be required for specific tasks and the importance of PPE in the protection of everyone.	• induction procedure • behaviour in workshop • routinely wearing PPE • wearing correct PPE • hazards • cleanliness • clear walkways • manual handling • First Aid procedures • fire procedures • tool and equipment safety

 **Selecting and using engineering tools and materials**	• The sourcing of tools means that each centre must inform the students of the procedures to be followed for the acquisition of tools and equipment. • The correct use of tools must be demonstrated before students are allowed to practise the skill. Reinforcement on the dangers of misuse of tools must be stressed. • Movement of tools to be completed in a safe manner. • Each tool has a function that it was designed for and use or misuse of the tool for any other task/purpose should be discouraged. • Students should be encouraged to report any faulty or worn tools. Each tool must be clean and free from defects at the start of the practical activities and at the end. Students must be made aware that if a tool is worn or becomes unusable that they are responsible for reporting the fault. • Tools should always be returned to their proper storage place. • Categories of materials - ferrous, non ferrous and non metallic. • Students informed of where each category is used. • Basic mechanical properties of materials explained. • Reasons for use of each material • The properties and reasons for use of common engineering materials.	• tool acquisition procedures followed during practical workshop sessions • correct number of tools used • carrying tools safely • using tools safely • clean and store tools safely and correctly • no tools left at end of session • use magnets • use correct materials in practical activities • use materials from drawing and specifications • safe use of materials • practicing specific trade skills

 **Quality checking own work**	• Students constantly check against the drawings for dimensions, materials, fits and sequence of operations. • Students should be made aware of acceptable quality of work • Introduction to tolerances and why they are required.	• quality checking as the work progresses • quality at the end of practical activity • checking and reporting on fit for purpose
 **Self review and evaluation**	• Students can be helped when you discuss their performance with them • Such discussions can help them get into the habit of evaluating their performance as a natural part of their work routine • Question students verbally about their performance as the work is proceeding in the workshop • Retain brief notes on the conversations of progress as evidence for employability • Students will have ample opportunity to demonstrate a positive attitude to learning because they have a lot to learn • A positive attitude to learning will also be reflected from the enthusiasm and expert knowledge of the staff member • Introduce practical activities very early • Interesting tasks and artefacts that will be enjoyed will aid with attention, following instructions, asking questions, taking advice, carry out quality checks and a desire to learn more	• conversation with tutor • quality checking • self evaluation exercises • number of attempts at tasks • listening to instruction • applying feedback • asking questions • practising skills • conversations with tutor • quality checking • assisting others • genuine participation in review process • perseverance All of the other employability skills

Resources

It is expected that this unit will be taught in an experiential manner within a fully equipped, safe and suitably arranged engineering workshop. Resources required for individual lessons are set out in each lesson plan.

Useful Websites

Listed below are websites that may be of assistance to you or your students:

- **Careers, Safety and Employability**

Careers Scotland
http://www.careers-scotland.org.uk/home/home.asp

SEMTA
http://www.semta.org.uk/

The Scottish Electrical Charitable Training Trust
http://www.sectt.org.uk/

EMTA Awards Ltd (EAL) Engineering and Technology industry awarding body
http://www.eal.org.uk/

Health and Safety Executive
http://www.hse.gov.uk

COSHH – Control of Substances Hazardous to Health
http://www.hse.gov.uk/coshh/

Employability Framework for Scotland
http://www.scotland.gov.uk/Topics/Business-Industry/Employability

- **Tools and Materials**

Tool-up (commercial site)
http://www.tool-up.co.uk/

Corus: automotive and mechanical engineering steels
http://www.corusgroup.com/en/products/bar_and_billet/steel_types/automotive_and_mechanical_eng

Encyclopedia
http://www.encyclopedia.com/

Wikipedia: free encyclopedia
http://en.wikipedia.org/wiki/Main_Page

Engineering: definition from Wikipedia free encyclopedia
http://en.wikipedia.org/wiki/Engineering

Technology Student
http://www.technologystudent.com/index.htm

FENC – aims to be the leading community for vocational blended learning
http://www.fenc.co.uk

Internet guide to engineering
http://www.eevl.ac.uk/engineering/

Mechanical Engineering magazine
http://www.memagazine.org/

Health and Safety: free leaflets: engineering
http://www.hse.gov.uk/pubns/engindex.htm

Technology at GCSE: Materials
http://www.btinternet.com/~hognosesam/gcse/page11.html

The Welding Institute
http://www.twi.co.uk

Mechanical Engineering Information and Tables
http://www.roymech.co.uk

Lessons, Materials and Tools

In the following lesson plans, which are intended as a guide only, the simple practical tasks are designed to integrate engineering skills such as:

- Identification, selection and use of materials
- Identification, selection and use of tools and equipment
- Interpretation of engineering drawings and specifications
- Employability skills

'Work Instruction Sheets' are included here but more detailed *'Workshop Task Sheets'* for the students are included at the end of the Student Support Section.

Actual timings and lesson content will be dependent on individual centres' timetabling arrangements.

Each lesson must start with the health and safety requirements that will be applicable to that particular lesson and any additional PPE that might be required.

Emphasis should also be placed on the requirements of students to be present and on time for the lesson – employers will not tolerate non-attendance or late-coming.

In each *Lesson Plan*, the tools and materials applicable to the lesson are listed. This list is for guidance only and can be supplemented as necessary.

It is anticipated that the use of engineering terminology, drawings, tools and materials will lead to discussion about roles and responsibilities in industry. This could include manufacturing processes or indeed any processes used in local firms.

Practical Tips

It is expected that as each basic practical skill is demonstrated, good practice will be emphasised. Also good trade specific hints or tips should be included in the lesson. It is also suggested that some or all of the following should be integrated with the range of practical activities:

- The use of employed apprentices attending college to aid workshop sessions
- The use of various speakers/experts/tradespersons to aid employability skills and knowledge of local industry
- The use of ICT if appropriate

Lesson 1

Identification and Use of Materials

Objectives:

- Identify and use materials by name and purpose – reasons for using a particular material – restricted to low carbon steel, stainless steel, copper, **aluminium** and non-metallic.
- Mechanical properties of materials – restricted to **hardness**, strength, **toughness**, magnetic field, corrosion resistance, weight and colour.
- Correct methods of handling, care of and storage of materials – the correct method of transportation, the care of the materials in terms of usage and storage should be demonstrated and emphasised

Resources:

- PPE
- Student Support Section materials
- Materials – low carbon steel (LCS), stainless steel, copper, aluminium, non-metallic
- Tools – scriber, hammer, centre punch, vice magnet

Learning and teaching process:

- use group discussion to determine the level of student knowledge of materials – develop this to discuss the need for selection in terms of service conditions, costs, specifications and drawings
- identify listed materials by name
- identify listed materials by purpose
- state mechanical properties of given materials
- state and demonstrate correct methods/techniques of handling and storage.

Lesson 2

Identification and Use of Tools

Objectives:

- Safe working practices, health and safety regulations and employability – to establish a level of knowledge and understanding of health and safety and employability.
- Identify and use tools by name and purpose – the safe use and recognition of tools in terms of their name and purpose. Emphasis should be on the correct use for each tool.
- Correct methods of handling, care of and storage of tools – the correct method of tool transportation, the care of the tool in terms of usage and storage should be demonstrated and emphasised.

Resources:

- PPE
- Student Support Section materials
- Tools:

• rule	• tape measure	• colourant
• scriber	• centre punch and hammer	• dividers
• surface table	• engineer's square	• micrometer
• hacksaws	• folding & forming	• snips/shears (various types)
• chisels	• drills	• taps
• dies	• files (various types)	• digital
• screwdrivers (various types)	• caliper (various types)	• bench vice
• clamps (various types)	• pliers (various types)	• hot working

Learning and teaching process:

- use group discussion to determine the level of student knowledge of health and safety issues; develop this to discuss the need for general health and safety in the workshop environment; emphasise the student's own health and safety and that of others in the workplace especially relating to tools and equipment.
- use small groups to establish requirements for a safe learning environment; what that environment looks like, feels like and sounds like. Small class groups of no more than 5 can design a poster that will list all the requirements necessary for a safe learning environment. Groups should be given around 20 minutes to complete the poster. Completed posters can be displayed around the workshop, if appropriate. Use results to promote awareness of a safe learning environment for individuals and class groups. This can then be extended to the general learning environment and the development of employability skills such as attendance, punctuality, working with others etc.
- identify listed tools by name
- identify listed tools by purpose
- state and demonstrate correct methods/techniques of using listed tools
- allow students to practise tool usage on simple tasks
- use group discussion to develop the need for proper care and storage of listed tools.

Lesson 3

Using tools and materials to mark, cut, shape and form

Objectives:

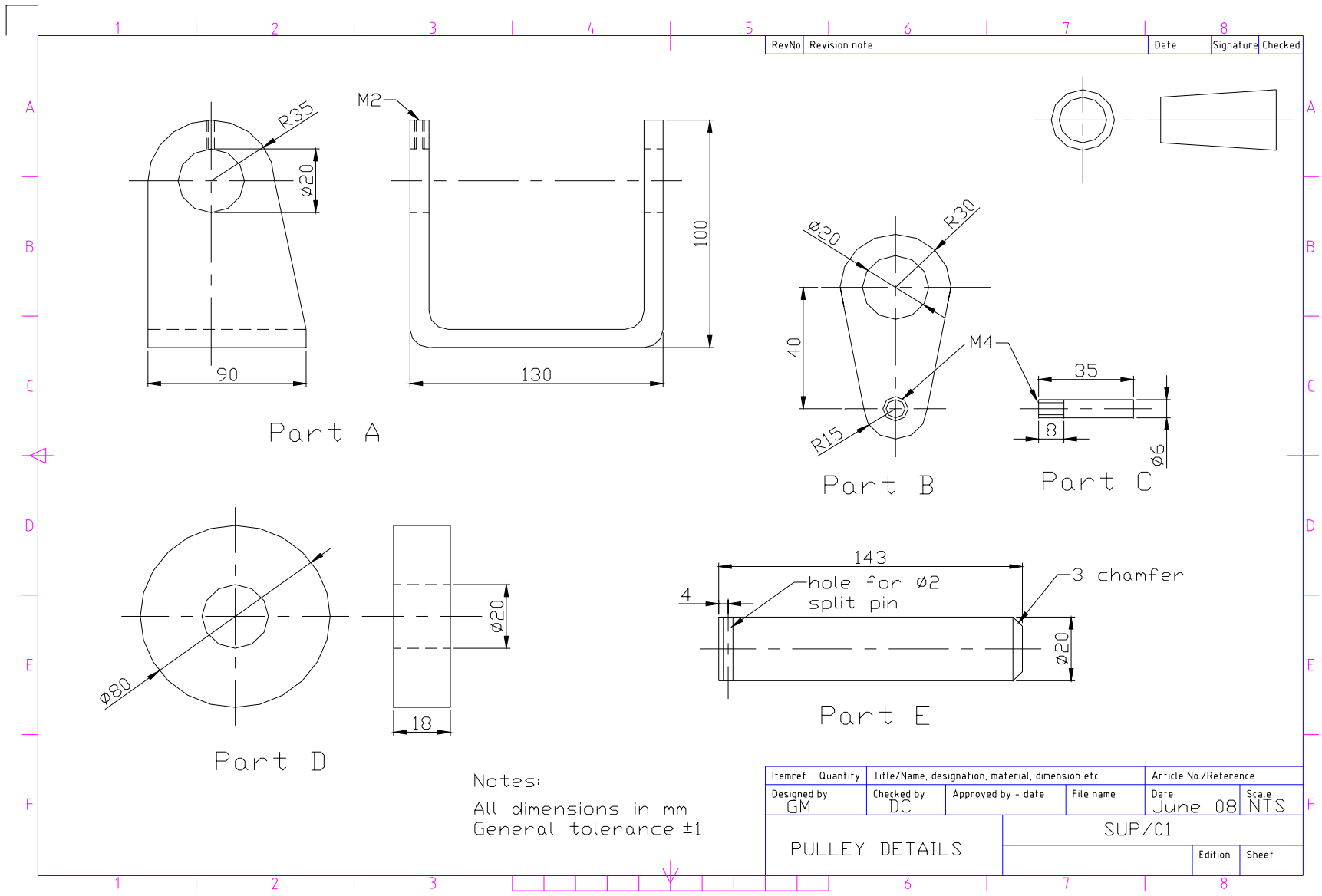
- Identify and use materials by name and purpose – reasons for using a particular material
- Identify and use tools and equipment to mark, cut, shape and form material
- Correctly and accurately check own work
- Demonstrate safe working practices.

Resources:

- PPE
- Student Support Section materials
- Material – LCS plate
- Tools:
    - rule
    - scriber
    - engineer's square
    - divider
    - centre punch
    - hammer
    - shears
    - files
    - folder
    - vice

Learning and teaching process:

- use the Pulley Parts (Part A) drawing to determine the required specification
- use group discussion to determine the level of student knowledge of materials; develop this to discuss the need for selection in terms of service conditions; costs, specifications and drawings
- identify listed materials by name
- identify listed materials by purpose
- demonstrate methods of marking out, cutting, shaping and forming
- highlight avoidance of scrap and making use of available resources
- identify checks for accuracy.


RevNo
Revision note
Date
Signature
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R35
ø20
M2
100
90
130
Part A
ø20
R30
40
M4
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35
8
ø6
Part B
Part C
ø80
ø20
18
Part D
143
4
hole for ø2
split pin
3 chamfer
ø20
Part E
Notes:
All dimensions in mm
General tolerance ±1
Itemref
Quantity
Title/Name, designation, material, dimension etc
Article No /Reference
Designed by
GM
Checked by
DC
Approved by - date
File name
Date
June 08
Scale
NTS
PULLEY DETAILS
SUP/01
Edition
Sheet

Lesson 4

Using tools and materials to mark, cut, shape, drill, tap and thread

Objectives:

- Identify and use materials by name and purpose – reasons for using a particular material
- Identify and use tools and equipment to mark, cut, shape, drill, tap and thread material
- Correctly and accurately check your own work
- Demonstrate safe working practices

Resources:

- PPE
- Student Support Section materials
- Material – LCS plate and bar
- Tools:
    - rule
    - scriber
    - engineer's square
    - micrometer
    - dividers
    - hacksaw
    - files
    - drills
    - taps
    - dies

Learning and teaching process:

- use the Pulley Parts (Parts B - E) drawing to determine required specification
- use group discussion to determine the level of student knowledge of materials; develop this to discuss the need for selection in terms of service conditions; costs, specifications and drawings
- identify listed materials by name
- identify listed materials by purpose
- demonstrate methods of marking out, cutting, shaping, drilling, **tapping** and threading
- introduce time management by allocating a notional time for a task
- identify checks for accuracy.

Lesson 5

Using tools and materials to assemble

Objectives:

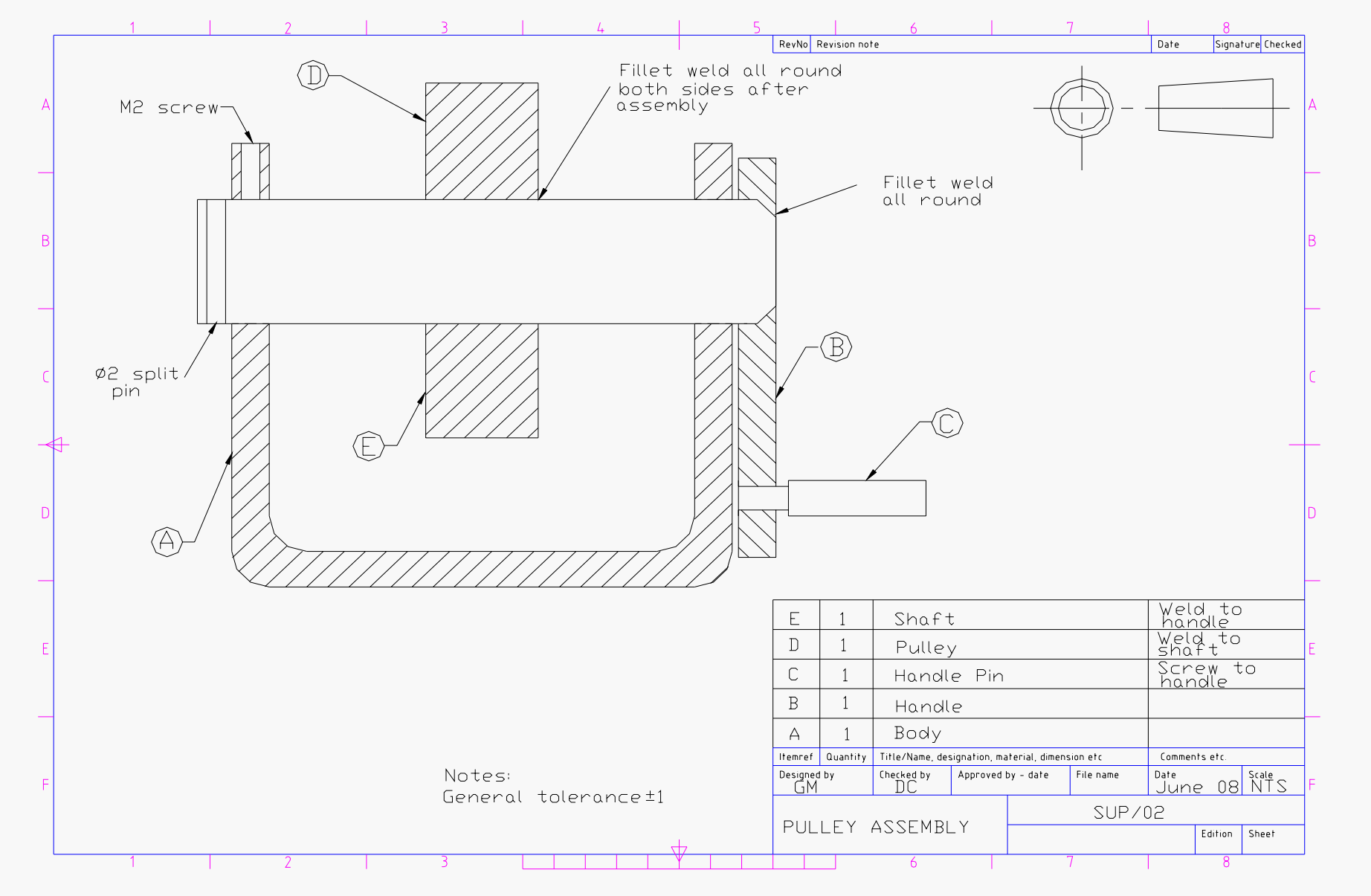
- Identify and use materials by name and purpose – reasons for using a particular material
- Identify and use tools and equipment to assemble
- Correctly and accurately check your own work
- Demonstrate safe working practices

Resources:

- PPE
- Student Support Section materials
- Material – LCS plate and bar as manufactured
- Tools:
  - rule
  - engineer's square
  - files
  - holding devices
  - MIG/MAG welder

Learning and teaching process:

- use the Pulley Assembly drawing to determine the required specification
- use group discussion to determine drawing and specification interpretation
- identify listed tools and parts by name
- identify listed tools and parts by purpose
- demonstrate methods of assembly
- identify checks for accuracy
- demonstrate checks for accuracy/specification
- use group discussion to allow students to share self-review


RevNo
Revision note
Date
Signature
Checked
M2 screw
D
Fillet weld all round both sides after assembly
Fillet weld all round
ø2 split pin
B
C
E
A
Notes:
General tolerance ±1
E 1 Shaft Weld to handle
D 1 Pulley Weld to shaft
C 1 Handle Pin Screw to handle
B 1 Handle
A 1 Body
Itemref
Quantity
Title/Name, designation, material, dimension etc
Comments etc.
Designed by GM
Checked by DC
Approved by - date
File name
Date June 08
Scale NTS
PULLEY ASSEMBLY
SUP/02
Edition
Sheet

Practical Activity Checklist

Checklist to monitor each student's progress in completing the lessons.

Student Name	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5

NOTE:

The more able candidates may complete the Practical Activities at a greater speed – on completion they could attempt some additional tasks at a comparable skill level. Where time does not permit the tackling of more sophisticated activities, those such as in the Support Materials for Engineering Skills: Mechanical (Intermediate 1) and Fabrication (Intermediate 1) will provide a useful exercise(s) for skill development although these are set at a lower skill and tolerance level.

Student Support Section

Tutor Note on Student Activities

This section includes both student notes and activities. Use of these materials is not mandatory and they are offered to centres as a flexible set of materials and activities which can be selected, altered and used in whatever way suits individual centres and their particular situation. You are encouraged to adapt and use the materials creatively in ways which will best engage your students.

It is not intended that the *Student Support Section* is issued to students as a complete pack. Rather the materials are designed to be issued in small sections only, to reinforce practical workshop activity. In the case of the student activities you might want to talk through the instructions with the learners and then give the instructions out on paper as reminders.

Similarly, and because of the technical nature of the subject and the terminology, handout materials should only be issued after the topic has been fully covered with the students.

Note:

There is a substantial degree of similarity between the Intermediate 1 Engineering Skills: Mechanical and Fabrication Units and this Intermediate 2 Unit.

This means that the student handouts and elements of the activities in this support pack are similar to the activities of the Intermediate 1 support packs. This is necessary for use with students who have not progressed through the Intermediate 1 route. The practical tasks that the students will work on however will require them to demonstrate a greater level of skill and to stricter tolerances.

Extension Activities

For students who have completed the *Engineering Skills: Intermediate 1* course the following additional activities are suggested:

- Risk assessment completion
- Interpretation of drawings using CAD
- Researching alternative manufacturing processes eg. forging; machining
- Comparison of alternative manufacturing processes eg. fabrication versus forging
- Positional welding
- Use of recognised engineering planning process
- Analysis of a self review

Employability Skills

This *Student Support Section* focuses on the trade-specific aspects of the unit. Further information and activities on the following aspects, which should be incorporated into learning and teaching throughout the unit, can be found in the *SFEU publication: Engineering Skills (Intermediate 2): Course Guidance and Employability Skills* support pack.

Tools and Materials

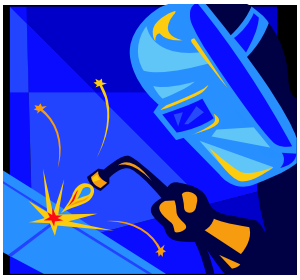
Information for students on the main tools and materials for this unit are provided. Further information on general workshop, measuring and marking and general joining tools is given in the SFEU publication - *Engineering Skills (Intermediate 2): Course Guidance and Employability Skills* support pack.

Welcome to Mechanical and Fabrication Engineering

In the Mechanical and Fabrication Unit you'll use tools, materials and equipment to make a range of artefacts (models) by cutting, shaping, forming and joining engineering materials such as metals and non-metals.

In order to cut , shape, form and join engineering materials you will learn to cut, shape, **drill** and tap holes, manufacture screw threads, form by hot and cold working and join using MIG/MAG welding, riveting, screwing and adhesives to manufacture a pulley.

The skills built into the unit include:



- health and safety awareness in the workshop
- **measuring** and marking
- reading drawings
- correct use of tools and equipment

You'll develop these skills in a series of lessons where you'll manufacture parts of a pulley and eventually assemble it. Your tutor may then give you further examples to work on when you've got the hang of the skills required.

Once developed and mastered, these skills can be transferred to other processes in engineering and will help if you decide to make a career in engineering.

You will learn to use tools **safely** to mark, cut, shape, form and join engineering materials.

Listen to your tutors – they have lots of experience to pass on to you.

If at any time you are unsure about what you're doing, just ask.

Engineers constantly ask questions – you need to do the same!

Your tutors are there to help you and will welcome your questions.

Enjoy the unit!

Introduction

This Mechanical and Fabrication unit is part of a course which will provide you with an opportunity to show quality skills in engineering activities.

The unit lets you see what it's like to work in an engineering workshop environment. The tasks you'll be doing will allow you to experience mechanical and fabrication engineering skills. This means that you have to understand the various aspects that will have an effect on you in the work environment.

We'll be looking at:

- safety
- basic engineering tools
- materials and processes
- employability

all of which are essential skills that you can transfer into almost any situation. The employability skills will help you to develop the skills that employers value and will give you an opportunity to think about your own performance.

The ability to read and interpret drawings is an important skill. When you can do this, you'll be able to tackle many projects and in any form of engineering employment you might eventually follow. The drawings will get more complex as you progress through the unit, but don't worry - we'll take it in easy stages.

If you have previously completed the *Engineering Skills: Intermediate 1* course you will find that you will develop additional practical and employability skills in this course. You will also be expected to work to closer tolerances in all practical activities. Your tutor may also allow you to investigate other engineering manufacturing methods that you could input to other course units.

Safety in the workshop

It's very important that you are aware of your responsibilities in the workshop - safe working practices, respect for yourself, care and use of tools and equipment and the safety of others working within the same environment.

Everyone in the workplace is responsible for their own safety and the safety of others who might be affected by their work. This means that, no matter how new and inexperienced you are to engineering **you** have a responsibility for safety.

The successful and safe completion of any practical work starts with everyone thinking about health and safety and what protection must be taken to ensure that the workplace is a safe and secure environment. Always:

- '**think safety**'
- **act responsibly**
- **plan your work**
- **keep your work area tidy.**

REMEMBER THAT THE USE OF HEAT BRINGS ITS OWN SAFETY ISSUES

Are you Employable?

All engineers have specific **practical skills** but they also have **employability skills**. Employability skills are valued by employers because they mean that their employees:

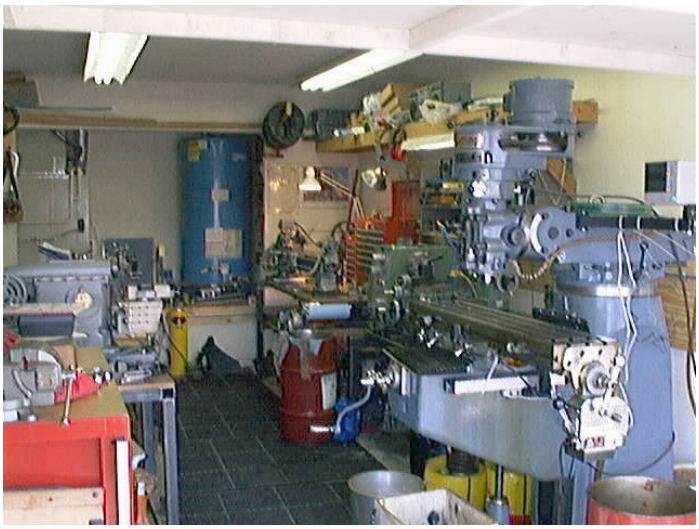
- understand the workplace and their responsibilities as employees, for example timekeeping, appearance, customer care
- can think about the work they've done and how they did it – and decide what they could do to improve it
- are keen to learn
- try to work out solutions to problems instead of walking away from them or leaving them to someone else
- are willing to give anything a go and don't mind change
- have confidence to set goals, reflect and learn from experience.

These employability skills are in this Unit and to get the most out of your unit you should always:

- maintain good timekeeping and attendance
- show health and safety awareness
- select and use engineering tools and materials
- quality check your own work
- self review and evaluate

Remember - this unit is designed to help you to decide if engineering is for you and to understand what **tradesperson**s actually do in their place of work.

Safety in the Workshop



Engineering workshops can be busy, noisy places with moving **machinery**. They pose a danger to you unless you are a trained engineer and know how to use the tools, equipment and machinery. A typical workshop will include benches fitted with vices with a wide variety of workshop tools that may include **power tools**.

In order to start learning engineering skills in the workshop you'll have to use materials, tools and equipment. However using these materials, tools and equipment can be dangerous to both you and others.

So the first consideration at the start of every practical session is:

Health and Safety

All tools are dangerous if used improperly or carelessly. Working safely is the first consideration of a good engineer. The good engineer will learn the safe and correct techniques for tool usage and machinery operation.

Anyone learning to operate machine tools must first learn the safety regulations and precautions for each tool or machine. **Most accidents are caused by not following safety procedures**.

There are **basic rules** for:

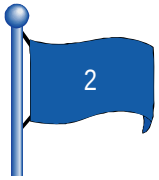
- safety in the workshop
- Personal Protective Equipment (**PPE**),
- the safe use of tools and equipment, and

very strict rules about our behaviour and conduct.

Most of the rules and regulations about **health and safety** are common sense and are designed to protect you and your fellow workmates from harm and injury.

The reality of work is that an employer's greatest consideration is to protect the workforce from injury and harm, so that each employee has a happy and safe working environment.

Safety First!



Activity

Safety for All

Safety is important for everyone, whether employee or employer. This activity is to help you to think from an employer's point of view.

1. Why do you think safety is so important from the employer's point of view?

2. What might happen if employees keep getting injured at work?

1. _____

2. _____

Name: **Date:**

Answers: Safety for All

- Investigation by the Health and Safety Inspectors
- Workplace closed down for safety reasons
- Losing employees
- Losing work
- High insurance costs.

Remember - Health and Safety is now the most important aspect of the world of work for everyone.

Basic Rules for Workshop Safety

Always wear the proper PPE. The most basic items of PPE are **overalls and safety footwear**.

No mucking about and no games – workshops are full of hazards and you could cause serious injury to yourself and others.

Listen to the instructions from your tutor and follow them closely.

In the workshop **always walk**, and like the Green Cross Code: **Look and Listen**

Know the **Exits** and procedures for all emergencies.

Know where the **emergency stop buttons** for all the equipment are located.

Wear sensible, **hard wearing clothes** under your PPE with all loose clothing securely tucked in.

No sports trousers and tops as these items are nearly always manufactured from plastic materials and are not suitable for engineering workshop use.

All walkways must remain clear at all times – **no obstructions.**

No jackets or bags in the workshop.

Be patient in the workshop - don't rush.

Use **tools** in the correct way and only for the particular task the tool was designed for.

Clean and store them properly at the end of each task.

Carrying tools from one part of the workshop must be done in the correct way.

When using hand tools with sharp edges keep both hands (and the rest of your body parts) behind the cutting edge.

Safety glasses must be worn when working with hand cutting tools, because most hand cutting tools are made of hardened steel and can break or shatter when used improperly.

Wear gloves in all practical activities if possible. Gloves protect your hands when using tools or working with engineering materials.

Although **noise hazards** can't always be eliminated, you can protect your ears from hearing loss by wearing **ear muffs**, **ear plugs**, or both.

Lifting things the wrong way can result in a **permanent back injury**. Back injury can be avoided if the **correct lifting procedures** are followed.

Exposure to electrical hazards will be minimal in the workshop but everyone needs constantly to be aware of the dangers of **electric shock**.

Report any worn or damaged tools or equipment immediately even if you weren't the person that damaged it!

Power Tools

If you use **power tools** then the following **rules** apply:

Listen very carefully to the correct operating instructions.

Observe the safety features and the holding positions of the tool.

Do not play with power tools and never operate them unless you have been properly instructed.

If the power tool has a **guard** or guards then the tool **must** be operated with these in place.

If you are not sure - **Ask**. Remember, a question is better than a sore finger.

Keep hands and fingers away from rotating machinery.

Cleanliness

Clean Work Area

It's important for everyone's health and safety that each work area is kept clean. This can be difficult in the middle of engineering activities, with various tools and equipment all being used at the same time, but you need to get into the habit of tidying the work area you are using.

Scrap and waste material must be removed to the correct storage bin regularly – don't wait for it to pile up. At the end of each practical class the work bench and work area must be brushed or wiped clean, ready for use the next time.

Hot Working

During the unit you will be using heat to form material and during welding.

You must ensure that you are suitably protected by using gloves and goggles when working with heat in addition to other standard PPE. Hot metal should be lifted and moved using tongs as even gloves may not fully protect you.

Any material that has been subjected to heat should not be left without suitable marking as someone might attempt to move it – always mark it with chalk.

Remember that any workbench where hot metal has been left will also be hot.

Any hot scrap material should immediately be put into the scrap bin not left on the workbench or floor.

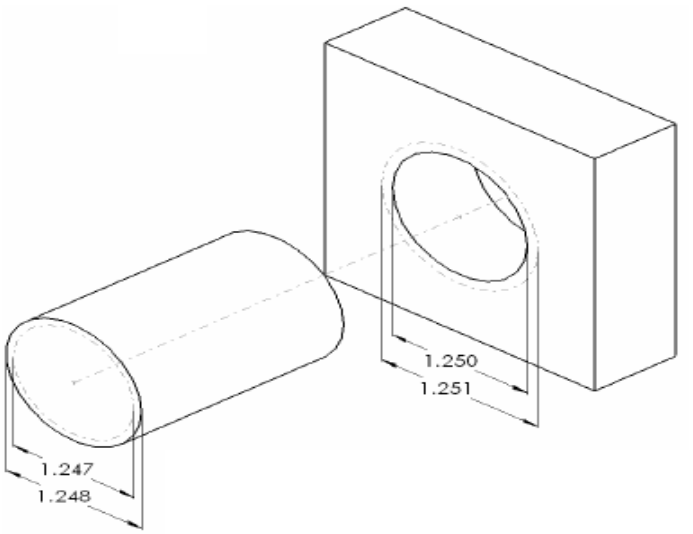
Tolerance

Tolerance is the amount of variation or error allowed and is shown on the drawing as plus or minus (±) a given amount. This means that when you are measuring something, you are allowed to be slightly out.

In this unit the tolerance is set at ±1 mm. This means that if you are measuring a length of 100 mm your measurement is allowed to be within the following range:

99 mm - 101 mm

This tolerance is set for *you*. Time served engineers have to work to much stricter tolerances! – in the drawing below the tolerance is set at 0.001mm.



Tolerance

The tolerance is given as ±1 mm. Complete the following table for the upper and lower limits:

Length in mm	Lower limit in mm	Upper limit in mm
100	99	101
50		
75		
150		
25		

Answers

Tolerance table

Length in mm	Lower limit in mm	Upper limit in mm
100	99	101
50	49	51
75	74	76
150	149	151
25	24	26

Tools and Materials

Measuring

Most engineering work needs to be as accurate as possible. This means that the measuring and marking of a work piece is very, very important.

Measuring is a very under-rated skill that most people take for granted. However engineers do not. A wrong measurement can cost valuable time and money to a firm, so what seems like a simple skill is in fact something that requires patience and practice.

Each time you measure and mark, try this simple rule:

measure twice
check twice
mark once
cut once

Accurate measurement also depends on your eyesight and the quality of the measuring tool.

Rule – Tape Measure

Engineers usually use a steel rule marked off in millimetres and centimetres.

For longer distances, such as those involved in large fabrications, steel or cloth tapes are used – these come in lengths from 3 metres to 30 metres.

Care should always be taken that these tools are only used for measurement as they are precision instruments.

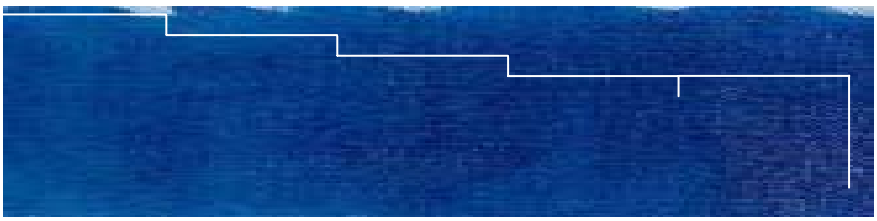
Marking Out

Marking out usually means the marking of lines on metal. These can be straight lines or circles or centres. If the marking out is on wood then a pencil line will be good enough, but on metal a pencil line would be very hard to see.

Marking Lines on Metal – Scribing

The surface on most metals can be shiny or dull but in both cases the marking lines can be difficult to see.

- On metal the line or mark is scratched ('scribed') on but even this can be difficult to see.
- Very often the metal is coloured with a dye (usually blue) and this lets the marked line stand out. This means that the tool used for marking must be sharp to give a good clear thin line.
- This **colourant** can only be applied if the metal surface is clean, - no grease and oil on the surface.



The thinner the line the more accurate the measurement and in engineering most measurements need to be as accurate as possible.

When marking out long, and perhaps not so accurate, distances such as fabrications French chalk is used without the need for a **colourant**. This chalk is hard and can be sharpened to a **chisel** point which is retained for a few markings.

Scriber

The scriber is made of hardened steel with a fine sharp point for marking fine lines on the metal surface. The point must be kept sharp to keep the lines fine for accurate marking.

Datum Points

Datum points are used in marking out.

- A datum point is really just a starting point.
- If more than one measurement is required, it makes good sense to make all measurements from a reference or datum point.
- The starting point on a map would be the same as a datum point.

So in marking out, a datum point is where all measurements start or where they are taken from.

Cutting

Filing

File Selection

Files can be classed by the file shape or by the spacing of the file teeth. The spacing of the file teeth is called the **pitch**, and it is the pitch that decides what file you should use for a particular material.

Name of File	***Use***	***Finish***
Bastard	rough work	rough
Second Cut	general work	reasonable
Smooth	finishing work	smooth

Remember, filing is a skill that only gets better with practice – don't expect to be great at it first time around!

So how do we file a piece of material?

Straight Filing

- Grip the handle and the point of the file and guide/push the file long ways across the work piece.
- Apply pressure with the hand that's on the point of the file and push with the hand on the file handle.
- Lift the file slightly off of the work piece on the return stroke.
- Practice makes perfect!

Start of stroke

End of stroke

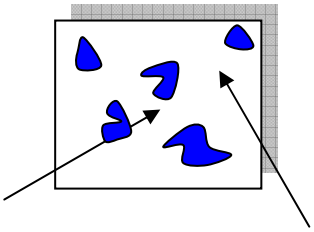
Draw Filing

Draw filing is for finishing work. Hold the file with both hands and draw across the work piece to give a smooth and even finish.

Filing Flat

The filing flat method is used to file flat a bigger surface area.

- Apply marking blue to a surface table and rub the work piece over it.
- This will show all the high spots.
- Take the file across the surface at 45°.
- After a few strokes, repeat this - but at right angles to the original direction. In the diagram the blue areas show the high spots.



Direction of second file strokes

Direction of first file strokes

First file strokes

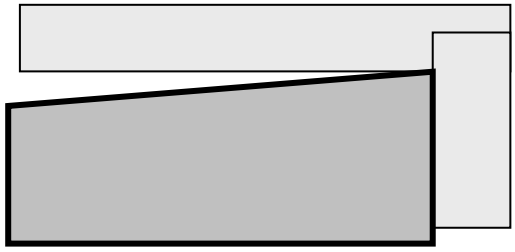
Second file strokes

Remember practice makes perfect!

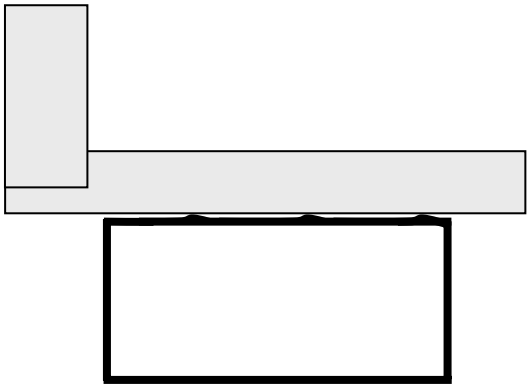
Filing Square

Filing square means that two edges of the work piece will be filed to make a right angle. Each edge is filed and constantly checked against an engineer's square. Like all filing this is a difficult skill to master.

Test for Square



Test for Level



Remember practice makes perfect !

Saw

A hand saw used to cut metal is known as a **hacksaw** and comes in various sizes such as a junior hacksaw.

The main type of hacksaw consists of a frame and a blade. The frame is adjustable to allow different sizes of blade to be inserted. The blade must be tensioned and inserted correctly. **Junior hacksaws** are not adjustable and the blade is tensioned by the spring of the frame.

Blades are classified by the number of teeth per unit length – normally the number of teeth in a 25mm length. You would normally cut thick materials with a coarse blade and thin materials with a finer blade. When cutting soft materials such as aluminium a coarse blade should always be used to prevent the teeth being clogged. A special blade should be used when cutting stainless steel. The hacksaw blade should never be used without the frame.

Snips and Shears

Snips and shears are used to cut sheet and thin material. There are several types in everyday use:

Straight snips - used for general purpose cutting, straight cuts and trimming excess material

Curved snips - used for cutting circles or irregular shapes

Universal shears - have offset handles allowing cuts to be made in any direction and come in right and left-handed versions.

Jeweller's snips - used on very thin material or when small cuts are required.

All of the above operate in a similar way to a pair of household scissors.

Bench shears – are usually fixed and mounted on the bench and are able to cut thicker material. They operate by a moving top blade being pressed down by a handle onto a fixed bottom blade.

Guillotines

These machines can be operated manually or by power.

Manual treadle guillotines rely on the strength of the operator's leg to push down on the treadle. This operates the top cutting blade to push the material against the bottom fixed blade. The treadle also operates the hold down clamp to stop the material moving. Only light **gauge** (thin) materials can be cut by this method.

Power guillotines are generally used for **repetitive work** and where thick materials need to be cut. Their capacities can go up to 20mm thick and they are able to cut long lengths. Power machines can be noisy during operations and ear protectors should be worn.

Both types of guillotine will be fitted with **guides** to assist squareness. They often have back and front gauges so you don't need to physically mark the material. This is useful when cutting a number of pieces of the same size.

Guillotines and similar machines should **never** be used without a guard in place.

You should **never** work from the back of the machine.

You should **always** keep your hands clear of the clamps and blades during operations.

On completion of the work all scrap material should be removed from the rear of the machine and power machines isolated (switched off).

Forming

The two types of forming we will cover in this unit are **hot** and **cold**. Some of the equipment used is common to both processes.

Hammers

Hammers are important tools that must be used correctly and safely.

They have a number of uses such as:

- shaping metal
- driving things into position
- tapping marking tools.

Hammers are available in a wide range of weights from 200g to 900g.

Bigger hammers are known as **sledge** and **lump** hammers and are used for heavy work.

Hammer handles or shafts are usually made from wood but some are now made from plastic. These materials absorb the shock when striking.

You should never strike one hammer with another as bits may chip off and damage your skin. When using a hammer you should not look at the hammer itself but at the end of what is being struck – this should help you not to hit your thumb!

A **mallet** is a hammer in the loosest sense. A mallet is used for the forming and shaping of sheet metal and is usually made from boxwood or hide. This allows metals with polished surfaces to be worked without undue surface damage. Mallets come in different forms depending on the use.

Hot Working

'Hot work' is sometimes known as forge work and is a series of different techniques using a wide variety of tools involving:

- heating
- shaping
- cooling
- re-heating, and
- re-shaping.

The metal is cut to the sizes laid down in drawings and the metal worker holds it in an open fire or other heat source with a pair of **tongs** until it is hot and **pliable**.

This hot metal is then transferred onto an **anvil**, where it is gradually shaped with blows from a variety of hammers and other tools.

Remember tools and other equipment will get **hot**!!

Stakes

Stakes are used with mallets and hammers to shape thin materials. They are fixed to the workbench and the metal is held by hand on the stake and is then struck to form the desired shape. Stakes can be used to form flanges, bends, safe edges (to stop you getting cut on the edge!), wired edges (like part of a hinge) and self-secured joints depending on the type used.

Power Forming

Manual methods of forming are only suitable for thin materials. Where there is a need to form thick materials the powered machines used are:

- press brakes
- power folders, and
- power rolls.

Press brakes have a moveable top beam that presses the material down on a fixed bottom beam. The top beam is fitted with a tool in the shape of a 'V' (Vee) at the required angle and the bottom beam incorporates a 'V' (Vee) at the same angle. Many tools can be manufactured to include a variety of angles and other shapes. The tools need to be manufactured from a 'tool steel' (ie. hard steel) to eliminate wear.

Power folders are similar to simple manual folders in that they usually have a swinging beam operating against a fixed beam to bend the material. The required angle can often be pre-set either by a computer control or by fitting a manual gauge to the machine.

Both types of power folders can bend material up to 25mm thick with a high degree of accuracy.

Power rolls can be horizontal or vertical – the choice is often dependent on the factory floor space and height.

Both horizontal and vertical power rolls are used in the same manner. You preset the ends and then insert the material into the machine. Then by increasing the pressure on the trailing roll and making numerous passes you allow the material to take a cylindrical shape.

Often thick material will be heated to aid forming.

A problem that occurs when **cold forming** all materials is called **spring-back**.

Spring-back is caused by the elasticity in the material resisting the pressure to make the new shape. It is overcome by over folding by a few degrees when making angular bends and by over rolling on cylinders.

The amount of over forming required depends on material type and thickness and is often incorporated in the manufactured tooling. In other instances it requires operator experience to incorporate the correct amount of over forming.

Keep your hands and yourself clear of a power forming machine when it is operating – it cannot stop immediately if something goes wrong.

Manual Forming

This is carried out by using rolls and folders with similar layouts to the powered machines already discussed, but operated by hand. Most machines for medium-duty work will be floor mounted but some machines for very light thicknesses can be bench mounted.

Joining

Screwing

Screws are part of a family of threaded fasteners that includes bolts and studs as well as specialised screws like carpenter's wood screws and the automotive cap screw. The threads (or grooves) can run right handed or left, tapered, straight, or parallel. There are two types of screws, machine and wood screws. Both are made of metal, however the machine screw used in engineering has a constant diameter and joins usually with nuts while the wood screw is tapered and grips to the actual wood surface. Other threaded fasteners are set pins, set screws and bolts which will not have the thread running the full length of the circular part.

ISO metric screw thread

- ISO metric screw threads are designated by the letter M followed by the major diameter of the thread in millimetres, eg. "M8".
- If the thread does not use the normal "coarse pitch" (e.g., 1.25 mm in the case of M8), then the pitch in millimetres is also added e.g. M8×1
- The diameter of hole to fit a particular size of thread is given in British Standards. A publication such as Zeus Charts will also give this information.

Tapping and Threading

A **tap** is used to cut a **thread** on the inside of a hole, enabling a bolt or screw to be screwed into it - similar to the function of a nut. **Taps** come in a variety of thread diameters and thread types, eg. metric, UNC, UNF, Whitworth.

Three different taps are needed to cut a thread in a material.

These taps have different names and shapes:

- taper tap
- intermediate tap
- plug tap

Taper Tap

The taper tap, sometimes known as number 1 tap, is used to start the thread. This tap doesn't cut the thread too deeply and has only a very gradual cutting action.

Intermediate Tap

The intermediate tap, sometimes known as number 2 tap, is used to cut a deeper thread and in many cases is the final tap used.

Plug Tap

The plug tap, sometimes known as number 3 tap is the final cutting tap for threaded holes and gives a good deep thread.

Tap Wrench (Dwang)

The tap wrench is the T bar which holds the tap securely for thread cutting.

Practical Tip

The tap cuts a cleaner thread if it is kept as clean as possible, so all swarf must be constantly cleaned away.

Tapping Procedure

Each tapping job requires careful planning before starting and each job might need a different size **tap** and drills.

Steps to follow:

1. Study the drawing or specification
2. Select the correct drill bit to cut the tapping hole from standard tables
3. Cut and **deburr** the hole
4. Select the **taper** tap and fit to the tap wrench
5. Apply **cutting compound**
6. Start cutting the shallow thread
7. Once the taper tap is biting into the material for a few turns, turn the tap in the reverse direction to clean the swarf
8. Continue to cut the thread remembering to reverse direction at least every 2 turns
9. Change the tap to the intermediate tap, apply cutting compound
10. Cut the thread as before
11. Change the tap to the plug tap, apply cutting compound
12. Cut the thread as before
13. Clean the taps and store correctly

14. Clean the work piece and work area.

Cutting Compound

Cutting compound is used to ease the cutting of threads in metals by lubrication. Cutting compounds come as pastes, sprays or oil.

Button (Split) Die

A **die** is used to cut a thread on the outside of a bar or cylindrical section. Dies come in a variety of thread diameters and thread types eg. metric, UNC, UNF, Whitworth.

Unlike the tap, only one die is needed to cut the thread. The die is split, hence the term **split die**, and held in the holder which can be adjusted to give a shallow or deep cut thread.

To gain the shallow cut the centre adjusting screw is tightened to open up the split

of the die - the outside adjusters are not tight at this time.

Practical Tip

The die cuts a cleaner thread if it is kept as clean as possible, so all swarf must be constantly cleaned away.

Threading Procedure

Each threading job requires careful planning before starting. Each threading job should only require a die, die holder and a file.

Steps to follow:

1. Study the drawing or specification
2. Use the file to **chamfer** the end of the bar. This will make it easier to start the thread cut.
3. Select the correct size of die and fit in the holder
4. Tighten the centre screw to open the split
5. Apply cutting compound to bar
6. Start cutting the shallow thread
7. Once the die is biting into the bar for a few turns, turn the die in the reverse direction to clean the swarf

8. Continue to cut the thread remembering to reverse direction at least every 2 turns
9. Slacken the centre screw and tighten the 2 outside screws to close the split
10. Cut the thread as before until bar is threaded
11. Clean the die and store correctly
12. Clean the work piece and work area.

Practical Tip

Both taps and dies can be used to clean and restore damaged threads in nuts and bolts, but in all cases it is recommended that new undamaged nuts and bolts are fitted.

MIG/MAG Welding

(Metal Inert Gas/Metal Active Gas)

Introduction

The MIG/MAG process is also just sometimes referred to as MIG (**Metal Inert Gas**) Welding. The term MIG is used mainly to indicate that a pure **inert gas** is being used in the process for the welding of aluminium or thin sheet material.

The principle of the process is that:

- heat is generated by striking an **arc** between a metal **electrode** and the work piece, with the electrode melting to form the weld bead (run).

This is a versatile process that is suitable for a large range of materials and thicknesses. It is often used in mass produced work but can be prone to fusion and penetration defects. (Your tutor will explain what this means! Write it down to help you remember.) These problems are reduced if the operator takes care with the correct set-up and maintenance procedures.

MIG/MAG Equipment

The main requirements are:

- power source
- wire feed system
- electrode wire spool
- cables
- torch
- shielding gas.

The other essential pieces of equipment are a **wire cutter**, to trim the end of the electrode wire, and a **wire brush** to remove **oxides** (rust) and impurities from the joint prior to welding as these may contaminate the weld.

Also required are the normal PPE **safety requirements** for any welding:

- gloves
- helmet
- apron
- spats (leather leggings that cover the top of the boots).

Power Source

MIG/MAG normally uses a DC transformer rectifier power source with the electrode wire having positive (+ve) polarity.

The speed of the wire feed controls the welding current (amps) which along with the arc voltage controls the heat input to the weld.

MIG/MAG is called semi-automatic welding because the power source automatically adjusts any slight variation in the arc length by increasing or decreasing the burn-off rate of the electrode.

Wire Feed System

The system includes the feed unit which supplies the electrode to the torch.

The **feed unit** can be:

- **integral** with the power source, or
- a separate unit on top of the power source

and there are two main types:

- pinch rolls which push the wire along the cable, or
- spool on gun which pulls the wire

The unit has two main functions:

- to provide a means to feed the electrode wire through the cable to the torch
- to provide adjustment to the speed of the wire feed and therefore alter the current setting.

Electrode Wire Spool

The wire is supplied on reels that are layer wound to ensure a smooth feed. Steel wire, if required, is coated with copper to provide protection from rusting, to aid lubrication and increase electrical conductivity.

- The large reels used that are part of the power source can weigh up to 20kg and care should be taken when handling.

- The smaller spools used on the gun are lighter and cause fewer problems with '**bird nesting**' as the electrode doesn't have such a great distance to travel from the drive rolls to the weld pool.
- Reels are usually supplied wrapped to protect the wire from dirt and moisture.

Wires come in different sizes (0.6mm - 1.6mm) depending on the thickness of the material to be joined and the type of material (eg. stainless steel, aluminium, steel) depending on the job specification.

Cable

The **harness** can be up to 5m in length but should be kept as short and straight as possible. The function of the harness is to transfer these from the wire feed unit to the torch:

- the electrode wire
- the shielding gas
- the welding current
- water cooling (if required) on large capacity machines.

The harness has an internal liner made of steel for hard wires and **teflon** for soft wires (aluminium) which makes it easy for the wire to glide through.

Torch

In addition to transferring the electrode wire to the joint, the **welding torch** performs two other functions:

- it transfers the welding current to the wire
- it provides the shielding gas for the arc and weld pool

The torches can be air or water cooled depending on the capacity of the power source.

- The air cooled torches rely on the shielding gas passing through the body to cool the nozzle and have a limited current carrying capacity.
- The nozzle directs the shielding gas towards the weld and encloses the contact tip which the electrode runs through and which is interchangeable depending on wire size.
- The tip should be changed as soon as wear is detected.

Shielding Gas

The **shielding gas** provides an envelope that protects the weld as it is being deposited. It also:

- **stabilise**s the arc
- aids the smooth flow of molten metal of the wire to the weld pool

Shielding gases for MIG/MAG welding are usually mixtures of argon, oxygen, CO_2 and helium.

When welding **steel** usually either CO_2 or an argon/CO_2 mixture is used. When welding **aluminium** either pure argon or an argon/helium mixture is used.

The gas regulator at the top of the cylinder should be fitted with a flow meter to give the operator the opportunity to adjust the gas flow to suit different applications.

Operating Characteristics of MIG/MAG Welding

The way in which the filler material is transferred across the arc is called the **mode of metal transfer**. This is controlled by:

- current setting
- voltage setting
- wire diameter

There are three main types of metal transfer desirable when using solid wire:

Dip transfer: used on thinner materials up to 6mm. This involves the wire actually dipping into the weld metal and causes a short circuit.

Spray transfer: used on thicker plate and is capable of high deposition rates. It can be only be used in the flat position on steel as the large molten pool tends to sag in position, but can be used in all positions in aluminium.

Pulse transfer: involves a pulsed current applied to the electrode wire where the weld metal is transferred in a regular series of droplets. This method allows a high degree of fusion and penetration and is used mainly in pressure vessel work. A special type of power source is required for pulse transfer.

MIG/MAG welding is usually carried out by pushing the nozzle towards the unwelded portion.

Weld Joints and Preparations

Generally weld joints can be classified as **butt joints** or **fillet joints**. The choice depends on material type, thickness and specification.

Butt joints can be further classified as:

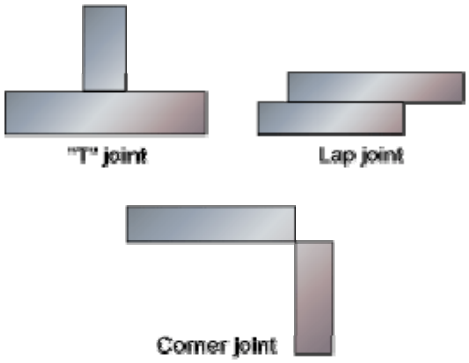
closed butt	open butt	single V
vee butt	double V butt	single U butt
single J butt	double J butt	single bevel butt
double bevel butt	edge butt	

Your tutor will show you different types.

*Single V Vee **Butt Weld***

Fillet joints are termed:

- T (tee) fillet
- lap fillet and
- corner fillet.



The edges of materials must be prepared for all butt joints except closed, open and edge, prior to welding. This preparation allows access to the root of the weld and aids penetration. The edge may be prepared by:

- grinding
- flame cutting
- nibbling
- edge planning

Welding related standards specify the dimensions and shape of preparations.

Welding Positions

It would be easy if all welds could be made in the flat position but this is not always the case and often welds have to made '***in situ***' and in these cases there's a greater chance of defects.

The main weld positions as specified by welding related standards are:

Flat – the weld lies equally on its axis and the molten pool is held in place by gravity.

Horizontal-vertical – one axis of the weld lies on the horizontal plane, the other on the vertical.

Vertical-up – welding starts at the bottom of a weld and continues in an upward direction.

Vertical-down – welding starts at the top of a weld and continues in a downward direction.

Overhead – the weld lies in the horizontal plane and is welded from underneath. This is the most difficult skill to master when welding.

Safety when MIG/MAG welding

The ***Health and Safety at Work Act*** places a duty on the employer to provide safe premises, plant and systems of work. It also places responsibility on employees to:

- co-operate with the employer
- take reasonable care for their own health and safety and for that of others
- avoid interfering with equipment provided for health and safety.

Health and safety **protection equipment** provided for during MIG/MAG welding must be used.

The main **hazards** associated with MIG/MAG welding are:

- electric shock
- **arc radiation** and burns
- fumes
- fire and explosion
- **compressed gas**es

Electric shock

It is always difficult to avoid contact with live parts of the welding circuit during welding.

The welder should:

- take off rings or metallic watch straps when welding
- stand on an insulating material, or wear **insulated** boots which must be dry
- use torches which are in good working condition
- place the power source away from the working area
- never work alone
- check that the insulation of cables are in good condition and that all connections are correctly fitted
- unsure that the welding equipment is correctly **earthed**
- work only in dry conditions
- never wrap cables around the body or areas of workbenches.

Arc Radiation and Burns

The electric arc generates three different types of radiation:

- ultra violet – which causes burns to skin and eyes (arc eye)
- visible light – which dazzles the eyes and causes tiredness
- infra-red – which causes burns and tiredness by heat from the arc

It is important to remember that arc radiation can be reflected from surrounding surfaces. A screen should be placed around the work area to protect other people round about you.

Because of the heat and rays during welding, all exposed skin must be covered. A form of severe sunburn will affect your skin if it is unprotected. Face and eyes should be protected by using a suitable face shield (helmet) fitted with the correct shade of filter.

Also, remember that welded metal and benches will stay hot for quite a long time after you've finished the welding operation. The process also involves the transfer of molten metal likely to cause sparks. Areas where welding has been recently completed should be marked as '**HOT'** as a warning to others. Remember molten steel has a temperature of about 1300^{o} C.

Fumes

All welding processes can produce large amounts of fumes and dust that can rise up from the weld into the welder's breathing zone.

This can be reduced by ensuring that the parent metals are as clean as possible with all paint and coatings removed and that all **parameters** are correctly set.

If fume levels cannot be reduced they must be removed by a form of local **extraction** placed as close as possible to the welding area and **vented** to an external source.

Fume extractor when hot welding

Fire and Explosion

Because of sparks and hot metal there is always the possibility of **fire**. The welder should check the surrounding area before starting work and should:

- check that appropriate fire fighting equipment is available
- remove all flammable (will burn) material where possible
- cover any remaining flammable material with fire resistant (will not burn) material
- inform others working nearby

Explosions during welding are normally the result of heat or flame coming into contact with containers that have previously contained explosive or flammable substances. If the welder is suspicious of previous contents of a container they should remove any residue by low pressure steam cleaning.

Compressed gases

In most cases MIG/MAG welding involves the use of a shielding gas stored in a pressurised cylinder. These cylinders are heavy and require lots of care during transportation – normally a cylinder trolley should be used. If a cylinder falls or is subject to high temperature seek immediate guidance from the gas supplier and/or the fire services.

Cylinders should be stored in an upright position in a secure ‘open’ area. Full and empty cylinders should be clearly marked and kept separate.

Any gases in use should be transferred to the welding area by a system of valves, regulators and hoses which must always be kept in good and serviceable condition. The main valve should always be cleaned before use and the cylinder turned off when not in use as many of the gases involved are asphyxiates (will suffocate you) if allowed to contaminate the atmosphere in sufficient quantities.

Materials

The materials mainly used in the Mechanical and Fabrication Unit are:

- **low carbon steel**
- copper
- aluminium
- stainless steel
- non-metallic.

Metals

Low carbon steel, copper, aluminium and stainless steel are metals. Metals can be classed in many ways but usually they fall into 3 main groups:

- **ferrous**
- non-ferrous
- **alloy**s.

Ferrous

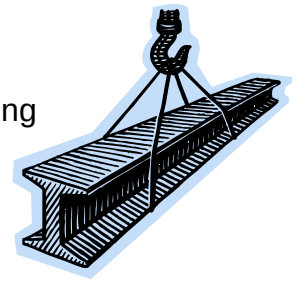
Ferrous metals contain iron and most can be magnetised. **Low carbon steel** is a ferrous metal. Also stainless steel is ferrous but some types cannot be magnetised.

Non-ferrous

Non-ferrous metals do not contain iron and usually cannot be magnetised. Aluminium and copper are non-ferrous metals.

Alloy

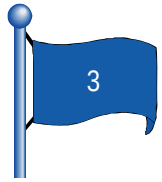
An **alloy** is a mixture of metal and other materials.



Metals are used in every field of engineering including the making of aerosol cans, medical joints, space shuttle, cars, trains, planes, kitchen appliances to computers. In fact it's difficult to think of an application that does not contain metal.

Metals are generally good conductors of heat and electricity. **Plastics** are usually the opposite.

Student Activities



Activity: Identification and use of tools

Your tutor will show you a selection of numbered tools – fill in the table with what you think they are called and what they do.

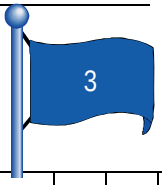
Tool	Tool Name	Tool Purpose
Tool 1		
Tool 2		
Tool 3		
Tool 4		
Tool 5		
Tool 6		
Tool 7		
Tool 8		
Tool 9		
Tool 10		

Activity: Material Identification

Your tutor will show you a selection of numbered materials – fill in the table with what you think they are called, what they can be used for and a property they possess.

Use simple workshop tests to identify the materials.

Material	Material Name	Use	Material Property
1			
2			
3			
4			
5			



Activity: Mechanical and Fabrication Crossword

	1										2					3								
					4																			
	5																							
													6			7								
					8					9														
10																		11		12				
					13																			
																							14	
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					16								17											
				18															19					
											20				21									
		22				23																		
										24														
		25																					26	
27												28												
											29													
					30					31							32							
							33																	
							34										35							
			36												37									

Name: **Date:**

Clues

Down

1 Used to cut metal (7)

3 L.C.S. (3, 6, 5)

4 Used to mark before drilling (6,5)

6 A thermal join (4)

10 Ball pein is one type (6)

9 Mark with this (7)

12 Used for gripping (6)

14 Protects your head (6)

17 Use to get the length (4, 7)

18 Part of a circle or welding term (3)

20 To cut a hole (5)

21 A part threaded fastener (4)

23 A gas such as Argon (5)

25 Like scissors for cutting metal (5)

26 Can be ring or open (7)

29 A single or double vee weld joint (4)

30 Shape hot metal over this (5)

32 Tap wrench name (5)

33 Greek God and engineering chart (4)

Across

2 This material will not corrode (9, 5)

5 Used with a hammer to cut metal (6)

7 Container for shielding gas (8)

8 No water from this (3)

9 Type of threaded fastener (5)

11 Reddish brown metal (6)

13 Can be thermosetting (7)

15 Usually snap headed (5)

16 Used to make marking easier (9)

19 Harden and - - - - - - (6)

20 Not the colour type (3)

21 Colour of Argon container (4)

22 Property of drawing out eg. wire (7)

24 Shapes metal (4)

27 Off with the head (10)

28 Not the senior cutter (6, 7)

31 - - - - Britannia (4)

34 Erode Celt (anag -9)

35 A mixed metal (5)

36 Used to form circular parts, can also be filled with bacon (5)

37 A warning one is triangular (4)

Crossword - Solution

	1 H										2 S	T	A	I	N	3 L	E	S	S	S	T	E	E	L
	A				4 C											O								
	5 C	H	I	S	E	L										W								
	K				N								6 W			7 C	Y	L	I	N	D	E	R	
	S				8 T	A	P			9 S	C	R	E	W		A								
10 H	A	M	M	E	R					C			L			R		11 C	O	12 P	P	E	R	
	W				E					R			D			B				L				
					13 P	L	A	S	T	I	C					O				I				
					U					B						N				E			14 H	
					N					E						S				15 R	I	V	E	T
					16 C	O	L	O	U	R	A	N	17 T			T				S			L	
					H								A			E							M	
				18 A									P			E			19 T	E	M	P	E	R
				R							20 D	I	E		21 B	L	U	E					T	
		22 D	U	C	T	23 I	L	E			R		M		O									
						N				24 F	I	L	E		L									
		25 S				E					L		A		T								26 S	
		N				R					L		S										P	
27 G	U	I	L	L	O	T	I	N	E			28 J	U	N	I	O	R	H	A	C	K	S	A	W
		P									29 B		R										N	
		S			30 A					31 R	U	L	E				32 D						N	
					N		33 Z				T						W						E	
					V		34 E	L	E	C	T	R	O	D	E		35 A	L	L	O	Y		R	
					I		U										N							
			36 R	O	L	L	S								37 S	I	G	N						

Activity: Measure, Mark, Cut and Form

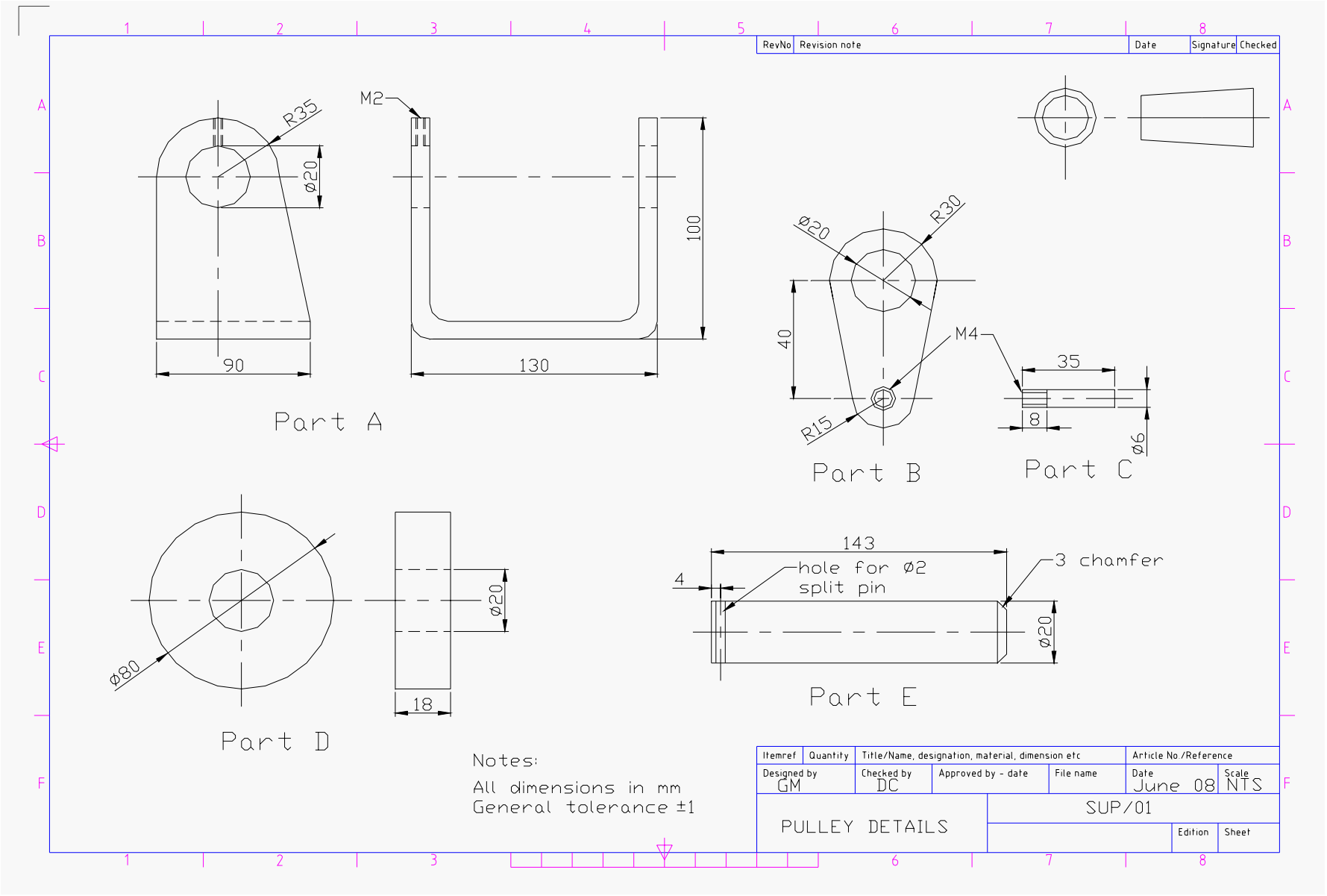
In this activity you will measure, mark, cut, shape and form a work piece.

This must be completed:

- using safe working practices, Health and Safety regulations and employability skills
- using correct measurement units from the specification (mm)
- using the correct marking tools
- using the tools solely for the intended purpose
- using the correct material
- using the correct cutting tools
- using the correct shaping tools
- using the correct forming tools
- by working to the specified **tolerance**
- by cleaning and storing tools
- by cleaning the work area on completion
- by recording how well you completed the activity
- using the *Pulley parts (Part A)* drawing on the next page

Remember Employability

Are you wearing your PPE?


RevNo
Revision note
Date
Signature
Checked
R35
ø20
M2
100
90
130
Part A
ø20
R30
40
M4
R15
35
8
ø6
Part B
Part C
ø80
ø20
18
Part D
143
4
hole for ø2
split pin
3 chamfer
ø20
Part E
Notes:
All dimensions in mm
General tolerance ±1
Itemref
Quantity
Title/Name, designation, material, dimension etc
Article No /Reference
Designed by
GM
Checked by
DC
Approved by - date
File name
Date
June 08
Scale
NTS
PULLEY DETAILS
SUP/01
Edition
Sheet

Activity: Measure, Mark, Cut, Shape, Drill, Tap and Thread

In this activity you will measure, mark, cut, shape, **drill**, tap and thread workpieces.

This must be completed:

- using safe working practices, Health and Safety regulations and employability skills
- using correct measurement units from the specification (mm)
- using the correct marking tools
- using the tools solely for the intended purpose
- using the correct material
- using the correct tools to cut
- using the correct tools to shape
- using the correct tools to drill
- using the correct tools to tap and thread
- by working to the specified tolerance
- by cleaning and storing tools
- by cleaning the work area on completion
- by recording how well you completed the activity
- by carrying out a quality check on your work
- using the *Pulley Parts (Parts B - E)* drawings on the previous page

Remember Employability

Were you on time for the class?

Activity: Measure, Mark, Assemble and Join

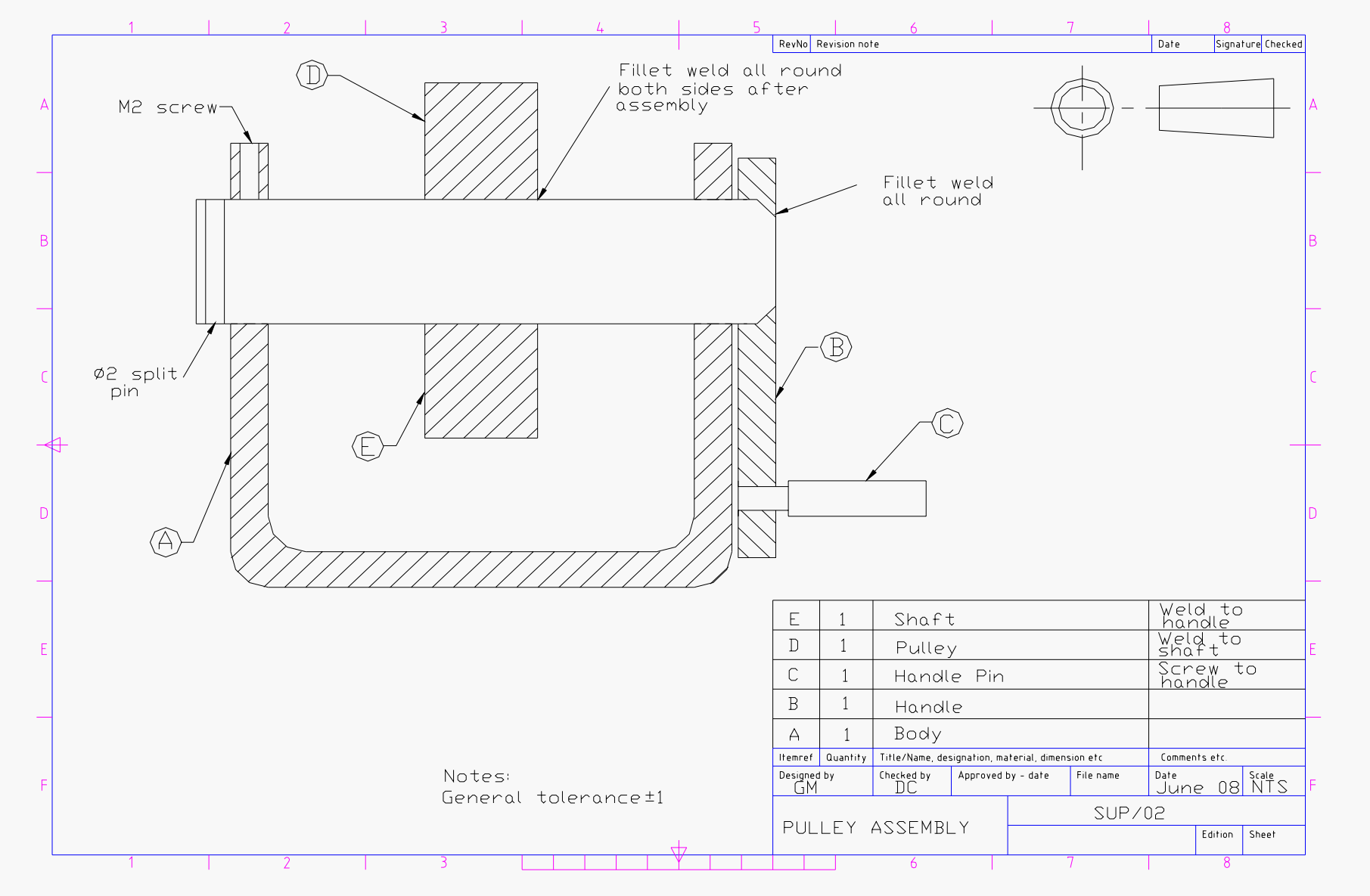
In this activity you will measure, mark, assemble and thermal join work pieces.

This must be completed:

- using safe working practices, Health and Safety regulations and employability skills
- using correct measurement units from the specification (mm)
- using the correct marking tools
- using the tools solely for the intended purpose
- using the correct previously manufactured materials
- using the correct assembly aids
- using the correct joining process(s)
- by cleaning and storing tools and aids
- by cleaning the work area on completion
- by carrying out a quality check on the assembly
- by recording how well you completed the activity
- Using the *Pulley Assembly* drawing on the next page.

Remember Employability

Did you interpret the drawing correctly?


RevNo
Revision note
Date
Signature
Checked
M2 screw
D
Fillet weld all round both sides after assembly
Fillet weld all round
Ø2 split pin
B
C
E
A
Notes:
General tolerance ±1
E 1 Shaft Weld to handle
D 1 Pulley Weld to shaft
C 1 Handle Pin Screw to handle
B 1 Handle
A 1 Body
Itemref
Quantity
Title/Name, designation, material, dimension etc
Comments etc.
Designed by GM
Checked by DC
Approved by - date
File name
Date June 08
Scale NTS
PULLEY ASSEMBLY
SUP/02
Edition
Sheet

Unit Questionnaire

This questionnaire is designed to help your lecturer find out how you feel about this unit.

You don't need to put your name on this questionnaire.

Instructions: Please complete this form by placing ✓ in the most appropriate box.

Unit Title:				
Lecturer's Name:			**Date:**	
		Strongly Agree	**Agree**	**Disagree**
1	The induction to this unit was helpful.			
2	My teacher/lecturer helped me through this unit.			
3	The resources and equipment were suitable.			
4	All Health and Safety information and practices were effective.			
5	My teacher/lecturer prepared me well for assessments.			
6	I was given constructive feedback.			
7	I was kept informed of my progress regularly.			
8	I enjoyed this subject.			

Please add any comments you feel are important to make this subject better:

Thank you for completing this questionnaire.

Glossary of Terms

Term	Meaning
Abrasive Cleaning	removing oxides etc. with a rough material such as emery paper or a wire brush
Alloy	an alloy is a mixture of metal and other materials
Aluminium	a white silvery metal that is very soft, is not hard wearing but has many uses in engineering
Arc	passing of electricity across metal
Arc	a curved line
Arc Radiation	the emission of rays from the electric arc
Ball Pein Hammer	a type of hammer used in metal work, it has a round part on the head, for shaping metal
Bird Nesting	when fine wire snags and bends back on itself
Brittleness	the inability to shape without fracture
Butt Weld	two pieces of metal joined edge to edge
Chamfer	to remove a sharp edge at the edge of a material
Chisel	a cutting tool used by engineers to cut metal
Colourant	a dye applied to metal to help in the marking process. The dye is usually blue in colour.
Compressed Gas	gas stored under pressure in a cylinder
Conduction	allow heat to pass through or along
Cutting Compound	a lubricant to assist in the cutting of a thread
Datum	a datum point is a reference or starting point when marking out
Deburr	the cleaning of the cut edge
Die	a cutting tool used to cut a thread on a bar
Drill	a cutting tool that cuts a round hole
Drilling Machine	a power tool used to turn the drill
Dwang	the T bar used to hold and turn the tap
Earthed	to stop the danger of electric shock
Electrode	the live wire for welding
Ferrous	a metal that contains iron and can be magnetised
File	a hardened metal bar with a series of sharp edges or teeth for removing excess metal

Filing	the skill of using a file to shape metal
Gauge	the thickness of a material
Hacksaw	a metal saw that cuts metal and plastic
Hardness	the resistance of a material to scratching
In situ	in the position that it will be used
Inert Gas	a gas which displaces oxygen (air)
Insulated	protection by a material to stop the flow of electricity
Integral	included within
Low Carbon Steel	an alloy made from iron and a small amount of carbon
Machinery	a device with moving parts that does useful work
Marking Out	the measuring and marking of lines on metal work pieces
Measuring	the ability to estimate the length, breadth etc. of an object in a unit of measurement such as a metre
Non Ferrous	a metal that does not contain iron and usually cannot be magnetised
Oxides	surface corrosion (rust)
Parameters	the various settings required
Plastics	man-made materials that are non-metals and have lots of common uses
Pliable	easily shaped
Power Tool	an electric or air powered tool that includes saws, drills, screwdrivers, chisels and grinders
PPE	Personal Protective Equipment is used to protect us from injury while we work
Presetting	forming the ends of a material before pressing or rolling to avoid flats
Pulse Transfer	power goes on and off consistently
Repetitive Work	where many of the same size and shape are required
Rotating Machinery	a machine with parts that turn
Shank - Drill	the shank is the body of the drill for gripping
Stabilise	to smooth out
Stressed	under load

Swarf	the metal cuttings from a machine when used to cut metal
Tap	a cutting tool used to cut a thread in a round hole
Taper	the taper means the shank is not parallel but reduces in thickness towards one end
Tapping	making a threaded hole
Teflon	a man-made nylon material which is non-stick
Thermoplastic	a plastic that can be heated and shaped many times
Thermosetting Plastic	a plastic that can be heated and shaped only once
Tolerance	the limit set above and below a measured value
Toughness	the ability to shape without fracture
Tradesperson	a person skilled in a particular craft
Weld Penetration	the amount that the weld burns into the parent material
Weld Preparations	the shape of the edge of a weld to allow penetration

These boxes are for you to add any other terms that you use during the course:
