

# IVQs in Engineering (2565)

Level 5 IVQ Advanced Technician Diploma  
in Engineering

- Mechanical and Electrical Engineering –  
Design and Manufacture
- Mechanical and Electrical Engineering –  
Plant Technology
- Mechanical and Electrical Engineering –  
Mechatronics

**(2565-03) (500/5794/7)**

Qualification handbook for centres



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**1 Giltspur Street****London****EC1A 9DD****T +44 (0)20 7294 2468****F +44 (0)20 7294 2400****[www.cityandguilds.com](http://www.cityandguilds.com)**

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## Important notice

Following the accreditation of the Technician IVQs in Engineering (2565) on the National Qualifications Framework of England, Wales and Northern Ireland (NQF), some changes have been made to the qualification, at the request of the Office of the Qualifications and Examinations Regulator (Ofqual), the qualifications regulator in England.

These changes took effect on 1 June 2009 and are outlined on pages 05–06.

**Note:** the content of the qualifications has not changed following accreditation.

### Changes to the qualification titles

The qualification titles have changed as follows:

Advanced Technician Diploma in Engineering – Applied Mechanical and Electrical Engineering (Design and Manufacture) (2565-03)  
*changed to*

**Level 5 IVQ Advanced Technician Diploma in Engineering (Mechanical and Electrical Engineering – Design and Manufacture) (2565-03)**  
Accreditation number: 500/5794/7

Advanced Technician Diploma in Engineering – Applied Mechanical and Electrical Engineering (Plant Technology) (2565-03)  
*changed to*

**Level 5 IVQ Advanced Technician Diploma in Engineering (Mechanical and Electrical Engineering – Plant Technology) (2565-03)**  
Accreditation number: 500/5794/7

Advanced Technician Diploma in Engineering – Applied Mechanical and Electrical Engineering (Control Systems) (2565-03)  
*changed to*

**Level 5 IVQ Advanced Technician Diploma in Engineering (Mechanical and Electrical Engineering – Control Systems) (2565-03)**  
Accreditation number: 500/5794/7

### Changes to the unit titles

Following the accreditation of the Technician IVQs in Engineering, each unit has been given an accreditation reference number which will appear on the Certificate of Unit Credit.

The content of the units is unchanged.

**Level 5 IVQ Advanced Technician Diploma in Engineering (Mechanical and Electrical Engineering – Design and Manufacture)**  
Accreditation number: 500/5794/7

F/502/2583 – Computer Aided Draughting 2 Practical Assignments  
J/502/2584 – Engineering Project  
R/502/2586 – Engineering Materials and Processes  
Y/502/2587 – Advanced Manufacturing and Management  
D/502/2588 – Advanced Manufacturing Engineering Practical Assignments  
K/502/2593 – Advanced Mathematics  
M/502/2594 – Mechanical Design Practical Assignments  
T/502/2595 – Applied Mechanics

**Level 5 IVQ Advanced Technician Diploma in Engineering (Mechanical and Electrical Engineering – Plant Technology) (2565-03)**  
Accreditation number: 500/5794/7

F/502/2583 – Computer Aided Draughting 2 Practical Assignments  
J/502/2584 – Engineering Project  
H/502/2589 – Plant Technology and Maintenance Procedures  
Y/502/2590 – Advanced Plant Practical Assignments  
D/502/2591 – Plant Hydraulics and Pneumatics  
H/502/2592 – Plant Hydraulics and Pneumatics Practical Assignments  
K/502/2593 – Advanced Mathematics  
M/502/2594 – Mechanical Design Practical Assignments

**Level 5 IVQ Advanced Technician Diploma in Engineering (Mechanical and Electrical Engineering – Control Systems) (2565-03)**  
Accreditation number: 500/5794/7

F/502/2583 – Computer Aided Draughting 2 Practical Assignments  
J/502/2584 – Engineering Project  
K/502/2593 – Advanced Mathematics  
A/502/2596 – Electronics  
F/502/2597 – Electronics Practical Assignments  
M/502/2594 – Mechanical Design Practical Assignments  
J/502/2598 – Advanced Electrical Principles  
L/502/2599 – Control Systems and Applications

**Registration for theory examination**

Registration process for the theory examination has not changed.

**Result submission for practical assessment**

Result submission process for the practical assessments has not changed.

**Change to the grading**

The grade 'Credit' has been changed to 'Merit'. All other grades are unchanged. The content of the units concerned is also unchanged.

**Notification of Candidate Results (NCR) and Certificate of Unit Credit (CUC)**

Notification of Candidate Results (NCR) and Certificate of Unit Credit (CUCs) continue to be available on completion of each assessment (theory or practical).

Final certificate will be issued on successful completion of all the required assessments.

**'Theory only' routes**

The 'Theory only' routes continue to be available as unaccredited qualifications.

**Changes to the certificate layout**

Certificates issued on completion of an accredited IVQ show the accredited title and the accreditation number for the qualification. The level in the accredited title refers to the NQF level the qualification is accredited at.

The certificate also lists all the units achieved, including the grade and the unit accreditation number.

The certificate carries the logos of the regulatory authorities in England, Wales and Northern Ireland indicating that the NQF accreditation only applies to these countries.

## Levels of City & Guilds qualifications

All City & Guilds qualifications are part of an integrated progressive structure of awards arranged over eight levels, allowing people to progress from foundation to the highest level of professional competence. Senior awards, at levels 4 to 7, recognise outstanding achievement in industry, commerce and the public services. They offer a progressive vocational, rather than academic, route to professional qualifications. An indication of the different levels and their significance is given below.

NQF level#	City & Guilds qualifications/programmes	Other qualifications*
8	Fellowship (FCGI)	Doctorate
7	Membership (MCGI) Master Professional Diploma Level 5 vocational awards NVQ/SVQ Level 5	Master's Degree Postgraduate Diploma Postgraduate Certificate
6	Graduateship (GCGI) Associateship (ACGI)**	Bachelor's Degree Graduate Certificate and Diploma
5	Level 5 IVQ Advanced Technician Diploma Full Technological Diploma	Higher National Diplomas Foundation Degree Diplomas of Higher and Further Education
4	Licentiate'ship (LCGI) Higher Professional Diploma Level 4 vocational awards NVQ/SVQ Level 4	Certificate of Higher Education
3	Level 3 IVQ Advanced Diploma Level 3 IVQ Specialist Advanced Diploma*** Level 3 IVQ Technician Diploma Level 3 vocational awards NVQ/SVQ Level 3	A Level Scottish Higher Advanced National Certificate in Education BTEC National Certificate/Diploma
2	Level 2 IVQ Diploma Level 2 IVQ Specialist Diploma*** Level 2 IVQ Technician Certificate Level 2 vocational awards NVQ/SVQ Level 2	GCSE grades A*-C Scottish Intermediate 2/Credit 5 Grade BTEC First Certificate
1	Level 1 IVQ Certificate Level 1 vocational awards NVQ/SVQ Level 1	GCSE grades D-G Scottish Intermediate 1/General 5 Grade Scottish Access 1 and 2

# National Qualifications Framework of England, Wales and Northern Ireland (NQF)

\* Broad comparability in level

\*\* Only graduates of the City & Guilds College, Imperial College of Science, Technology and Medicine, are awarded the Associateship (ACGI)

\*\*\* Part of a new qualification structure which is being introduced across the IVQ provision

IVQ International Vocational Qualifications

NVQ National Vocational Qualifications

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# IVQ in Engineering 2565

## About City & Guilds

We provide assessment and certification services for schools and colleges, business and industry, trade associations and government agencies in more than 100 countries. We have over 120 years of experience in identifying training needs, developing assessment materials, carrying out assessments and training assessment staff. We award certificates to people who have shown they have mastered skills that are based on world-class standards set by industry. City & Guilds International provides a particular service to customers around the world who need high-quality assessments and certification.

## Introduction to this programme

We have designed the Advanced Technician Diplomas in Mechanical and Electrical Engineering programme for those undergoing training or employed in this area of work. The programme aims to reflect the international nature of the knowledge and skills and activities needed for different countries or cultures.

We provide certificates for all work-related areas at seven levels within our structure of awards shown in Appendix B. This programme covers level 4. The standards and assessments for the diploma (level 3) and the certificate (level 2) are published separately.

### Certificate

The certificate (about 350-400 guided learning hours) provides a broad introduction to the theory and practical sides of engineering for a front-line worker or a person beginning an academic training programme.

### Diploma

The diploma (about 900 guided learning hours) provides more practice involving a broader range of skills appropriate to a person who may also supervise, or who is going on into higher education.

### Advanced diploma

The advanced diploma (about 900 guided learning hours) takes these skills to the level appropriate for a person preparing for or working in first-level management. It is also appropriate for someone who wants to receive specialised training at a high level.

We stress that these figures are only a guideline and that we award certificates and diplomas for gaining and showing skills by whatever mode of study, and not for periods of time spent in study.

## Full Technological Diploma

We will award the Full Technological Diploma (FTD) in Engineering to someone who is at least 21, who has had at least two years relevant industrial experience, and who has successfully finished the assessments for the diploma and advanced diploma levels of this award. If candidates enter for this diploma, they must also send us a portfolio of evidence to support their application.

## Making entries for assessments

Candidates can only be entered for the assessments in this subject if the approved examination centres agree. Candidates must enter through an examination centre we have approved to carry out the assessments for 2565 Technician Awards in Engineering.

There are two ways of entering candidates for assessments.

### Internal candidates

Candidates can enter for examinations if they are taking or have already finished a course at a school, college or similar training institution that has directed their preparation whether by going to a training centre, working with another institution, or by open learning methods.

### External candidates

These are candidates who have not finished a programme as described above. The examination centres must receive their application for entry well before the date of the examination concerned. This allows them to act on any advice you give about assessment arrangements or any further preparation needed.

In this publication we use the term 'centre' to mean a school, college, place of work or other institution.

External candidates carrying out practical assignments and projects, will need extra time and guidance to make sure that they meet all the requirements for this part of the assessment.

## Resources

If you want to use this programme as the basis for a course, you must read this booklet and make sure that you have the staff and equipment to carry out all parts of the programme. If there are no facilities for realistic practical work, we strongly recommend that you develop links with local industry to provide opportunities for hands-on experience.

## Assessments

### Summary

#### Advanced Diplomas

We use a numbering system to allow entries to be made for our awards. The numbers used for this programme are as follows.

We use award numbers to describe the subject and level of the award.

#### Award number

2565-03 Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Design & Manufacture

Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Design & Manufacture

Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Plant Technology

Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Plant Technology

Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Control Systems

Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Control Systems

We use component numbers to show units for which we may award a certificate of unit credit.

#### Component numbers

- 028 Electronics
- 029 Electronics Practical Assignments
- 030 Engineering Project Practical Assignment
- 033 Materials and Processes
- 034 Advanced Manufacturing and Management
- 035 Advanced Manufacturing Engineering Practical Assignments
- 036 Mechanical Design Practical Assignments
- 037 Applied Mechanics
- 038 Plant Technology and Maintenance Procedures
- 039 Advanced Plant Practical Assignments
- 040 Plant Hydraulics and Pneumatics
- 041 Plant Hydraulics and Pneumatics Practical Assignments
- 042 Advanced Electrical Principles
- 043 Control Systems and Applications
- 047 Advanced Mathematics
- 048 Computer Aided Draughting 2 Practical Assignments

We use these numbers throughout the booklet. You must use these numbers correctly if you send forms to us.

## Assessments required for specific awards

### Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Design & Manufacture

To carry out what is needed for the Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Design & Manufacture, candidates must be successful in all of the following assessments.

[2565-03-030] Engineering Project Practical Assignment

2565-03-033 Materials and Processes (written paper which lasts two hours)

2565-03-034 Advanced Manufacturing and Management (written paper which lasts three hours)

[2565-03-035] Advanced Manufacturing Engineering Practical Assignments

[2565-03-036] Mechanical Design Practical Assignments

2565-03-037 Applied Mechanics (written paper which lasts three hours)

2565-03-047 Advanced Mathematics (written paper which lasts three hours)

[2565-03-048] Computer Aided Draughting 2 Practical Assignments

(Total four written papers)

The practical assignments are carried out during the learning programme and should be finished by the date of the written examination so you can send all the results to us. (See Appendix A).

To receive this award candidates must complete the following practical assignments.

030/1, 035/1, 035/2, 036/1, 036/2, 036/3, 036/4, 036/5, 048/1, 048/2, 048/3 and 048/4

(Total twelve practical assignments)

### **Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Design & Manufacture**

To carry out what is needed for the Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Design & Manufacture, candidates must be successful in all of the following assessments.

- 2565-03-033 Materials and Processes (written paper which lasts two hours)
  - 2565-03-034 Advanced Manufacturing and Management (written paper which lasts three hours)
  - 2565-03-037 Applied Mechanics (written paper which lasts three hours)
  - 2565-03-047 Advanced Mathematics (written paper which lasts three hours)
- (Total four written papers)

There are no practical assignments for this award.

### **Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Plant Technology**

To carry out what is needed for the Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Plant Technology, candidates must be successful in all of the following assessments.

- [2565-03-030] Engineering Project Practical Assignment
  - [2565-03-036] Mechanical Design Practical Assignments
  - 2565-03-037 Applied Mechanics (written paper which lasts three hours)
  - 2565-03-038 Plant Technology and Maintenance Procedures (written paper which lasts three hours)
  - [2565-03-039] Advanced Plant Practical Assignments
  - 2565-03-040 Plant Hydraulics and Pneumatics (written paper which lasts three hours)
  - [2565-03-041] Plant Hydraulics and Pneumatics Practical Assignments
  - 2565-03-047 Advanced Mathematics (written paper which lasts three hours)
  - [2565-03-048] Computer Aided Draughting 2 Practical Assignments
- (Total four written papers)

The practical assignments are carried out during the learning programme and should be finished by the date of the written examination so you can send all the results to us. (See Appendix A).

To receive this award candidates must complete the following practical assignments.

- 030/1, 036/1, 036/2, 036/3, 036/4, 036/5, 039/1, 039/2, 041/1, 041/2, 048/1, 048/2, 048/3 and 048/4.
- (Total fourteen practical assignments)

### **Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Plant Technology**

To carry out what is needed for the Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Plant Technology, candidates must be successful in all of the following assessments.

- 2565-03-037 Applied Mechanics (written paper which lasts three hours)
  - 2565-03-038 Plant Technology and Maintenance Procedures (written paper which lasts three hours)
  - 2565-03-040 Plant Hydraulics and Pneumatics (written paper which lasts three hours)
  - 2565-03-047 Advanced Mathematics (written paper which lasts three hours)
- (Total four written papers)

There are no practical assignments for this award.

### **Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Control Systems**

To carry out what is needed for the Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Control Systems, candidates must be successful in all of the following assessments.

2565-03-028	Electronics (written paper which lasts three hours)
[2565-03-029]	Electronics Practical Assignments
[2565-03-030]	Engineering Project Practical Assignment
[2565-03-036]	Mechanical Design Practical Assignments
2565-03-042	Advanced Electrical Principles (written paper which lasts two hours)
2565-03-043	Control Systems and Applications (written paper which lasts three hours)
2565-03-047	Advanced Mathematics (written paper which lasts three hours)
[2565-03-048]	Computer Aided Draughting 2 Practical Assignments
	(Total four written papers)

The practical assignments are carried out during the learning programme and should be finished by the date of the written examination so you can send all the results to us. (See Appendix A).

To receive this award candidates must complete the following practical assignments:

029/1, 029/2, 029/3, 030/1, 036/1, 036/2, 036/3, 036/4, 036/5, 048/1, 048/2, 048/3 and 048/4.

(Total thirteen practical assignments)

### **Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Control Systems**

To carry out what is needed for the Advanced Technician Diploma in Mechanical and Electrical Engineering Theory – Control Systems, candidates must be successful in all the following assessments

2565-03-028	Electronics (written paper which lasts three hours)
2565-03-042	Advanced Electrical Principles (written paper which lasts two hours)
2565-03-043	Control Systems and Applications (written paper which lasts three hours)
2565-03-047	Advanced Mathematics (written paper which lasts three hours)
	(Total four written papers)

There are no practical assignments for this award.

## Fixed and free date assessments

We provide assessments in two ways

### a Fixed date

These are assessments which are carried out on dates and times we set. These assessments have no brackets around their numbers.

### b Free date

These are assessments which are carried out at a college or other training establishment on a date or over a period which the college chooses. These assessments have brackets around their numbers.

In this programme the written assessments are fixed date. The practical assignments and the project are free date.

You must carry out assessments according to our International Directory of Examinations and Assessments. If there are any differences between information in this publication and the current directory, the Directory has the most up-to-date information.

## Results and certification

Everyone who enters for our certificates, diplomas, and advanced diplomas receives a 'Notification of Candidate Results' giving details of how they performed.

If candidates successfully finish any assessment within this programme (for example, any one of the examination papers) they will receive a certificate of unit credit towards the certificate or diploma for which they are aiming. We grade coursework assessments (practical assignments) as pass or fail. We grade written assessments on the basis of fail, pass, credit or distinction. The certificate of unit credit will not mention assessments which they do not enter, which they failed or from which they were absent.

Each certificate or diploma clearly states what candidates need for full certification at the relevant level, allowing schools, colleges and employers to see whether they have met the full requirements.

If candidates successfully finish all the requirements for a full certificate or a diploma, they will automatically receive the appropriate certificate.

We will send the 'Notification of Candidate Results', certificates of unit credit, certificates, diplomas and advanced diplomas to the examination centre to be awarded to successful candidates. It is your responsibility to give the candidates the certificates. If candidates have a question about the results and certificates, they must contact you. You may then contact us if necessary.

We will also send you a results list showing how all candidates performed.

## How to offer this programme

To offer this programme you must get approval from us. There are two categories of approval.

### Subject approval

We give approval to offer a teaching course based on this syllabus.

### Examination centre approval

We give approval to enter candidates for examinations.

To be approved by us to offer a teaching course you must send us the application form.

To enter candidates for examinations you must be approved by us as an examination centre. For this programme it is possible to act as a registered examination centre only, and accept external candidates. Approved examination centres must provide suitable facilities for taking examinations, secure places to keep the examination papers and materials, and may have an appointed visiting verifier to review practical work.

After we have received and accepted an application, we will send an approval letter confirming this. You can then send entries in at any time using the International Directory of Examinations and Assessments for guidance.

**Please note that in this section we have provided an overview of centre approval procedures. Please refer to the current issue of 'Delivering International Qualifications – Centre Guide' for full details of each aspect of these procedures.**

## Other information

### Designing courses of study

Candidates for the various Technician Awards in Engineering will have come from different backgrounds and will have different employment and training experiences. We recommend the following:

- carry out an assessment of the candidates' achievements so you can see what learning they already have and decide the level of entry they will need; and
- consider what learning methods and places will best suit them.

When you assess a candidate's needs, you should design teaching programmes that consider:

- what, if any, previous education qualifications or training the candidate has, especially in the various general vocational education certificates we provide; and
- what, if any, previous practical experience the candidate has which is relevant to the aims of the programme and from which they may have learned the relevant skills and knowledge.

When you choose learning methods and places, you should consider the results of your assessments and whether the following are available.

- Open or distance learning material.
- Workplace learning that can be carried out on site or between you and a local workplace. This will allow the candidates access to specialised equipment and work experience.
- Working with other registered centres to share facilities.
- Opportunities for co-operative learning between candidates for different certificates who need to gain similar skills.

As long as the candidates meet the aims of this learning programme the structures of courses of study are up to you. So, it is possible to include extra topics that meet local needs.

You should avoid teaching theory alone. As far as possible the practical work should be closely related to work in the classroom so that candidates use their theory in a realistic work environment. You can use formal lectures in the classroom with appropriate exercises and demonstrations. Candidates should keep records of the practical work they do so they can refer to it at a later date.

We assume that you will include core skills, such as numeracy, communication, working with people, and organisation and planning throughout a teaching programme.

### Presentation format of the programme

#### Competence statements

Each unit consists of a number of competence statements which are generally followed by a range statement.

For example:

'33.12 Explain the factors which influence failure of metals.

**Factors:** creep, fatigue'

In the above statement the word 'factors' is given as a range which the candidate should be familiar with. Candidates should cover the complete range. When a range starts with the abbreviation 'eg' the candidates only need to cover some of the ranged areas or you can use suitable alternatives.

Competence statements cover practical skills and knowledge. The knowledge needed is closely linked to the practical competences, so it is best to teach the two together so that the candidate appreciates the topic more.

#### Practical assignments

You should make sure all practical assignments are supervised and instructors should make sure that the results reflect the candidate's own work. You must hold all the documents and associated materials in a file (portfolio) for each candidate for eight weeks after the application for a certificate. You must also keep separate records of the dates of all attempts by each candidate.

### Entry Levels

We consider the following programmes to be relevant preparation for this programme.

Technician Diploma in Mechanical and Electrical Engineering (2565)

Ordinary Technician Diploma in Mechanical and Electrical Engineering (8000)

We also consider the following Pitman Qualifications award as relevant alongside this programme.

English for Speakers of Other Languages – higher intermediate level

## Progression routes and recognition

A number of UK universities and other higher-education institutions will accept success at diploma or advanced diploma level of this programme for direct entry onto higher-level programmes. The decision to accept a candidate on to a degree programme, and the level of entry, is up to the institution. We provide details of organisations recognising achievement in this programme.

## Useful publications

We can provide a list of suggested text books covering specific areas of this programme. We may also have knowledge about other support materials. You should make sure that you have the latest information. We will automatically send updated lists to centres we have approved to offer this programme.



Plain English Campaign's Crystal Mark only covers the regulations.

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# Syllabus

## IVQ in Engineering 2565

### Component numbers and titles

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028 Electronics
029 Electronics Practical Assignments
030 Engineering Project Practical Assignment
033 Materials and Processes
034 Advanced Manufacturing and Management
035 Advanced Manufacturing Engineering Practical Assignments
036 Mechanical Design Practical Assignments
037 Applied Mechanics
038 Plant Technology and Maintenance Procedures
039 Advanced Plant Practical Assignments
040 Plant Hydraulics and Pneumatics
041 Plant Hydraulics and Pneumatics Practical Assignments
042 Advanced Electrical Principles
043 Control Systems and Applications
047 Advanced Mathematics
048 Computer Aided Draughting 2 Practical Assignments

## Introduction

This unit aims to provide a broad coverage of both analogue and digital electronics. An approach, with worked examples and calculations where appropriate, based on hands-on practical work is recommended. Where possible, candidates should be introduced to the uses of discrete component and integrated circuits in a range of small signal and large signal practical applications.

## Practical competences

The candidate must be able to do the following:

- 28.1 Design, construct and test a single stage transistor amplifier based on or incorporating either a bipolar junction transistor (BJT) or field effect transistor (FET).  
**Test:** measure dc voltages, determine the voltage gain, frequency response and maximum signal handling capability
- 28.2 Build and test a power amplifier incorporating integrated circuits.  
**Test:** mid band voltage gain, frequency response, measure ac power output, dc supply power, calculate conversion efficiency
- 28.3 Observe the effects of wave shaping networks on ac signals.  
**Signals:** sine wave, square wave

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Integrated circuits

- 28.4 Describe the construction and operation of basic analogue and digital IC circuits in both bipolar and FET forms including CMOS.  
**Circuits:** differential pair, complementary pair, dc feedback pair, NAND/NOR logic gates
- 28.5 Identify from manufacturers' data a range of integrated circuits.  
**Integrated circuits:** operational amplifiers, combinational sequential logic gates, regulators
- 28.6 State the scale of integration relating to integrated circuits and identify appropriate applications of each.  
**Scale and applications:** SSI (basic logic gates), MSI (counters and shift registers), LSI (RAM and ROM), VLSI (microprocessors eg 6502, Z80), SLSI (Pentium)
- 28.7 Explain the use of active devices as current sources and sinks in integrated circuits.

### Signal shaping and coupling circuits

- 28.8 Describe, with the aid of waveform sketches, the operation of capacitor resistor (CR) circuits and the effects of the time constant on both square wave and sine wave input signals.  
**Circuits:** differentiating, integrating
- 28.9 Determine by calculation and graphically the signal attenuation, phase shift and frequency response of typical CR coupling circuits with sine wave inputs.
- 28.10 Sketch voltage waveforms to show the effect of junction diodes and voltage reference diodes (Zener), used in conjunction with suitable biasing voltages, to form shaping and clamping circuits.

### Basic transistor circuits

- 28.11 Describe briefly the construction and operation of transistor bipolar junction transistors (BJT) and field effect transistors (FET).
- 28.12 Explain how the dc operating conditions of common source and common emitter amplifier circuits are established and stabilised by use of current and voltage feedback biasing.
- 28.13 Describe the operation of transistors as a switch and the limiting conditions.  
**Transistors:** BJT, FET  
**Limiting conditions:** saturation, cut-off
- 28.14 Describe briefly the causes of switching delays in a transistor switching circuit.  
**Causes:** stored charge, transfer of charge
- 28.15 Calculate the dc voltage and current levels established by the use of current feedback biasing in single stage amplifier circuits.  
**Circuits:** common emitter bipolar transistor, common source field effect transistor
- 28.16 Explain the terms 'small signal' and 'large signal' operation of a transistor.
- 28.17 Define the ac 'small signal' parameters for a bipolar transistor in common emitter configuration.  
**Parameters:** forward current ratio ( $h_{fe}$ ), input resistance ( $h_{ie}$ )
- 28.18 Define the ac 'small signal' parameters for a field effect transistor in common source configuration.  
**Parameters:** forward transfer conductance ( $g_{fs}$  or  $g_m$ ), output resistance ( $g_{os}$  or  $1/r_o$ )
- 28.19 Calculate, using simplified ac equivalent circuits, the voltage gains of single stage amplifier circuits.  
**Circuits:** common emitter, common source
- 28.20 Compare the performance of bipolar and field effect transistor amplifiers using the results obtained in 28.19.

### Basic amplifier circuits

- 28.21 Describe the operation of a single stage transistor amplifier circuit.  
**Circuit:** common emitter (BJT), common source (FET)
- 28.22 Explain the occurrence of signal distortion under the Class A operation.
- 28.23 Calculate the voltage and current gains of two stage amplifiers using the appropriate equivalent circuits and typical device parameters.  
**Amplifiers:** common emitter, common source  
**Devices:** bipolar transistor, field effect transistor
- 28.24 Sketch typical 'small' signal frequency response curves (gain in dB against logarithmic frequency) for an amplifier and state the reasons for the fall in gain at low and high frequencies.
- 28.25 Define bandwidth as the frequency band between the two frequencies where the gain of an amplifier has fallen by 3dB from its mid band value.
- 28.26 Explain briefly the various modes (classes) of operation used in amplifiers.  
**Modes:** A, B, C, D

### Feedback

- 28.27 Describe briefly, using block diagrams, the basic principles of positive and negative feedback.
- 28.28 Define feedback factor and calculate the gain of an amplifier having a negative feedback loop with a feedback factor  $\beta$ .

- 28.29 Explain the effects of negative feedback.  
**Negative feedback:** reduces noise, reduces distortion, stabilises gain, modifies bandwidth, modifies input and output impedances
- 28.30 Describe the types of negative feedback and compare their performances.  
**Performance:** voltage gains ( $A_v$ ), current gain ( $A_i$ ), input impedance ( $Z_{in}$ ), output impedance ( $Z_o$ )  
**Types:** series, parallel, voltage, current
- 28.31 Describe briefly the operation of simple single stage negative feedback amplifier circuits and determine their approximate gain.  
**Circuits:** unbypassed emitter (or source) resistor, emitter (or source follower), voltage feedback from output to input

### Oscillators

- 28.32 Define oscillators as general feedback amplifiers with positive (regenerative) feedback.
- 28.33 State the conditions for sine wave oscillations to be generated.  
**Conditions:** gain must be infinite, loop gain must be 1, must occur at a single frequency
- 28.34 Describe the operation of a 3-stage RC phase shift oscillator.
- 28.35 Describe with the aid of a circuit diagram, the operation of a single tuned-circuit oscillator.
- 28.36 Perform calculations of gain and frequency of RC and tuned-circuit oscillators.
- 28.37 State the frequency range of RC and LC oscillators.  
**Frequency range:** RC – low frequency and audio, LC – high frequency
- 28.38 State the advantages of using crystal control in oscillators.  
**Advantages:** preset frequencies, high stability

### Operational amplifiers

- 28.39 State the characteristics of a typical operational amplifier.  
**Characteristics:** open loop gain is high, input resistance is high, output resistance is low, gain bandwidth product is 1 MHz
- 28.40 Sketch the open loop response of a typical operational amplifier and show how this is modified by negative feedback to produce a constant gain bandwidth product.
- 28.41 Sketch the circuits and describe the operation of a range of operational amplifier circuits incorporating resistor capacitor networks.  
**Amplifiers:** integrator, ac coupled amplifier having a high-pass frequency response, dc amplifier having a low pass frequency response

28.42 Calculate the mid band voltage gains and bandwidths of the high-pass and low pass operational amplifier circuits given typical component values.

**Amplifiers:** ac coupled amplifier having a high-pass frequency response, dc amplifier having a low pass frequency response

### Basic logic circuits

28.43 Explain, using truth tables, the operation of a range of 2 input logic gates.

**Logic gates:** AND, OR, NAND, NOR, XOR

28.44 Reduce simple Boolean expressions using logical relationships.

28.45 Construct combinational gate systems to implement simple Boolean expressions or truth tables.

28.46 Explain the need for a latch.

28.47 Draw the circuit and explain the operation of a simple RS latch.

28.48 Explain with the aid of a logic diagram the operation of the cross-coupled NAND or NOR gates.

### Power output circuits

28.49 Compare efficiencies of a range of amplifiers.

**Amplifiers:** Class A, Class AB, Class B

28.50 Describe typical applications for the range of amplifiers in 28.49 above.

28.51 Explain, with the aid of a diagram, the operation of a Class B push-pull amplifier (using complementary transistors).

28.52 State the effect of cross-over distortion and explain how it can be eliminated.

28.53 Explain, with the aid of a diagram, the operation of a Class AB push-pull amplifier incorporating a bootstrap capacitor.

28.54 Using manufacturers' data sheets, select a range of power ICs for given applications, eg LM380, TDA2030.

### Use of instruments

28.55 Explain the functions of the main controls of an oscilloscope.

**Controls:** channel gain, time base speed, sync/trigger, time base mode (alternate scan or switching)

28.56 Describe applications of the oscilloscope.

**Applications:** waveform observation, measurement of amplitude, time, frequency and phase

28.57 Describe the use of probes to improve the performance of oscilloscopes and electronic instruments at high frequencies.

**Types of probe:** low capacitance, multiplier, rectifier

28.58 Define the terms 'resolution' and 'accuracy' of instruments and determine typical values from manufacturer's data.

28.59 Calculate errors in instrument readings and the tolerance which must be applied arising from practical limitations.

**Limitations:** loading due to instrument impedance, resolution and accuracy of the instrument

28.60 Describe the operation and use of a simple logic probe.

### Optoelectronics

28.61 Explain that light energy generates electron-hole pairs in a semiconductor.

28.62 Describe briefly the construction and operation of a range of photo sensitive devices.

**Devices:** photo resistive cells (light-dependent resistors – LDR), photovoltaic cells (solar cells), photo diodes, photo transistors

28.63 Compare the relative merits of a range of photo sensitive devices.

**Merits:** cost, size, linearity, dynamic range, speed, temperature sensitive

**Devices:** light dependent resistors, solar cells, photo diodes and transistors

28.64 Describe typical applications of photo sensitive devices.

**Typical applications:** light operated relay, power source (solar cell), light meter, light sensitive switch

28.65 Describe the emission of light generated by passing current through a forward biased junction (light emitting diode – LED).

28.66 Determine, using manufacturers' or suppliers' information, details of commercially available light emitting diodes.

**Details:** emission colour, forward voltage, maximum current and power ratings, size

28.67 Sketch circuits for the operation of various LEDs and calculate suitable component values from the information obtained in 28.66.

28.68 Describe briefly the construction and operation of an opto-isolator and state typical applications.

**Applications:** completely isolated non-electrical coupling, switching high voltage loads from sensitive low voltage sources

28.69 Describe the principle of light propagation along a fibre optic cable and explain the associated terms.

**Terms:** step index, graded index

28.70 Sketch a simple block diagram and describe the operation of a fibre optic communication system.

**System:** transmission, receiver, fibre optic cable

# Assessment

## Test specification for written paper Electronics (2565-03-028)

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Integrated circuits	5
Signal shaping and coupling circuits	5
Basic transistor circuits	10
Basic amplifier circuits	15
Feedback	10
Oscillators	10
Operational amplifiers	5
Basic logic circuits	10
Power output circuits	10
Use of instruments	10
Optoelectronics	10

# 029 Electronics Practical Assignments

## Practical assignment 029/1: Wave Shaping

### 1 Competence reference

28.3

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Components: wave shaping networks as shown in section 6, figure 1a, 1b and 1c mounted on a suitable test board.

Test equipment: function generator, 2-channel oscilloscope and suitable test leads.

Support facilities: drawing and writing materials, copy of Section 3 and copy of section 6.

#### 2.3 Instructor notes

Candidates are required to connect up the networks in section 6, observe the effects of wave shaping networks on ac signals, record the results and explain the operation of the networks.

Candidates have 3 hours to complete this assignment.

Instructors must ensure that health and safety regulations are observed at all times.

### 3 Candidates' instructions

3.1 You have three hours to complete this assignment. In this assignment you are required to:

- observe the effects of wave shaping networks on ac signals
- record all results
- explain the operation of the networks.

#### 3.2 Signal connections and test procedures

3.2.1 Connect, in turn, each of the networks shown in section 6, figures 1a, 1b and 1c to a signal generator and oscilloscope as shown in figure 2.

3.2.2 For network 1a, set the function generator to give a 1kHz sinewave having an amplitude of 24V peak to peak. This waveform is monitored on channel 1 of the oscilloscope.

3.2.3 Observe the output waveform of the network on channel 2 of the oscilloscope.

3.2.4 Sketch the shape of the waveform and record the voltage levels of both the negative and positive peaks measured with respect to zero volts of dc.

3.2.5 Replace network 1a with network 1b and repeat steps 3.2.3 and 3.2.4 keeping the same input signal.

3.2.6 Replace network 1b with network 1c and change the input signal setting to a 1kHz square wave having an amplitude of 20V peak to peak. Repeat steps 3.2.3 and 3.2.4.

#### 3.3 Conclusions

3.3.1 For the networks, explain the reasons for the shapes of the output waveforms and the associated voltage levels.

3.3.2 Write your name on your work and hand it in to your instructor.

## 4 Marking

- 4.1 Assignment completed in three hours. ( )
- 4.2 **Signal connections and test procedures**
- 4.2.1 Each of the networks shown in section 6, figures 1a, 1b and 1c connected in turn to a signal generator and oscilloscope as shown in figure 2. [ ]
- 4.2.2 For network 1a, the function generator set to give a 1kHz sinewave having an amplitude of 24V peak to peak. This waveform monitored on channel 1 of the oscilloscope. [ ]
- 4.2.3 Observation of the output waveform of the network on channel 2 of the oscilloscope. [ ]
- 4.2.4 The shape of the waveform sketched and the voltage levels recorded of both the negative and positive peaks measured with respect to zero volts of dc. [ ]
- 4.2.5 Network 1a replaced with network 1b and steps 3.2.3 and 3.2.4 repeated, keeping the same input signal. [ ]
- 4.2.6 Network 1b replaced with network 1c and the input signal setting changed to a 1kHz square wave having an amplitude of 20V peak to peak. Steps 3.2.3 and 3.2.4 repeated. [ ]
- 4.3 **Conclusions**
- 4.3.1 For the networks, explanation given for the reasons for the shapes of the output waveforms and the associated voltage levels. [ ]
- 4.3.2 Name written on work and handed in to instructor. [ ]

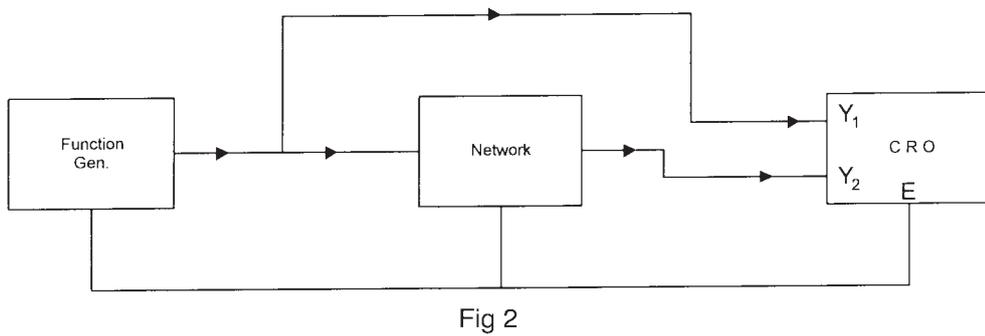
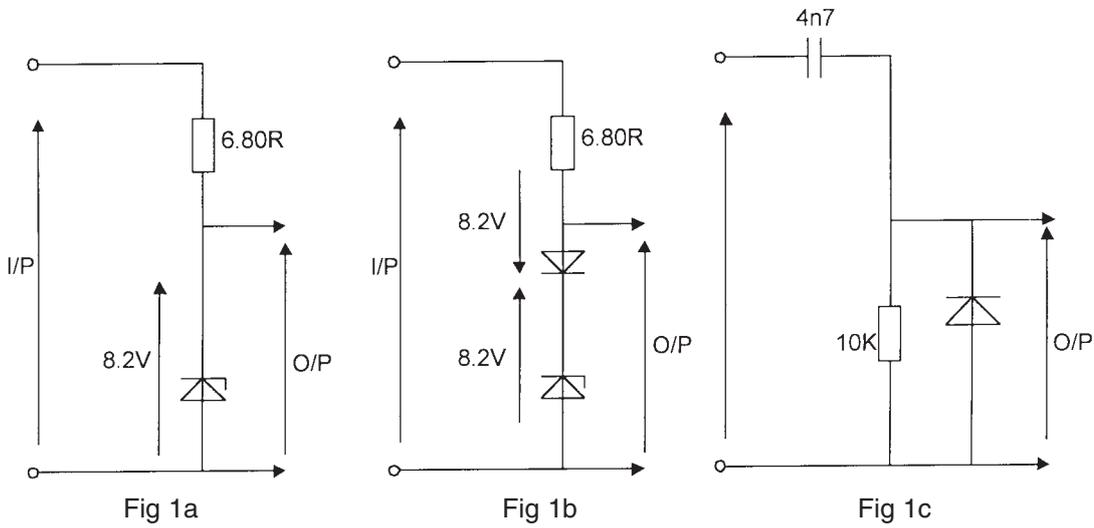
## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ].

A period of several days must elapse before an unsuccessful candidate may retake this assignment. An alternative circuit design should be used.

## 6 Assignment documentation

### 6.1 Wave shaping



# 029 Electronics Practical Assignments

## Practical assignment 029/2: Design and Build a Common Emitter Transistor Amplifier

### 1 Competence reference

28.1

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Components: Range of electronic components: 1 transistor, 4 resistors and 2 capacitors. Suitable circuit board, strip board or printed circuit board.

Tools: kit of small tools and soldering iron for electronic assembly. Resin-cored solder.

Test equipment: dc power supply, multimeter (analogue or digital), audio signal generator, 2-channel oscilloscope and suitable test leads.

Support facilities: graph or squared paper, drawing and writing materials. Transistor data sheet. Copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to design, build and test a single stage junction transistor common emitter amplifier.

Candidates have 6 hours to complete this assignment.

Instructors must ensure that health and safety regulations are observed at all times.

### 3 Candidates' instructions

3.1 The time allowed for this assignment is 6 hours. You are advised to read all the instructions before commencing work. If you do not understand all the instructions then please ask your instructor.

In this assignment you are required to identify the components (see circuit diagram section 6), solder the components to the matrix board to the layout in the circuit diagram.

3.2 List the components required from the diagram (section 6).

3.3 Plan the layout on graph (squared) paper and ensure the layout is economical.

3.4 Check the layout is correct with your instructor.

3.5 Insert the components in the strip board and insert pins in appropriate holes in the board to anchor the components.

3.6 Solder the components to the pins to form the amplifier circuit shown.

3.7 Power up circuit using 9 volt power supply unit (or battery).

3.8 Check dc levels throughout circuit and record the values.

3.9 Input 1 kHz signal from signal generator and display input and output on an oscilloscope. Adjust input amplitude to avoid any distortion.

3.10 Draw the input signal and the output signal and measure the amplitudes.

3.11 Calculate the voltage gain of the amplifier from the results obtained in 3.10.

3.12 Increase the input amplitude to a maximum value without causing significant distortion and record the value.

3.13 Put your name on your work and hand it in to your instructor.

## 4 Marking

- 4.1 Assignment completed in 6 hours. ( )
- 4.2 The components correctly listed. [ ]
- 4.3 The layout correctly and economically planned on graph (squared) paper. [ ]
- 4.4 The layout checked by the instructor. [ ]
- 4.5 The components inserted in the strip board and pins inserted in appropriate holes in the board to anchor the components. [ ]
- 4.6 The components soldered to the pins to form the amplifier circuit shown. [ ]
- 4.7 Circuit powered up using 9 volt power supply unit (or battery). [ ]
- 4.8 dc levels checked throughout circuit and the values recorded. [ ]
- 4.9 Input 1 kHz signal input from signal generator and input and output signal displayed on an oscilloscope. Input amplitude adjusted to avoid any distortion. [ ]
- 4.10 The input signal and the output signal drawn and the amplitudes measured. [ ]
- 4.11 The voltage gain of the amplifier calculated from the results obtained in 4.10. [ ]
- 4.12 The input amplitude increased to a maximum value without causing significant distortion and the value recorded. [ ]
- 4.13 Work handed in to instructor. [ ]

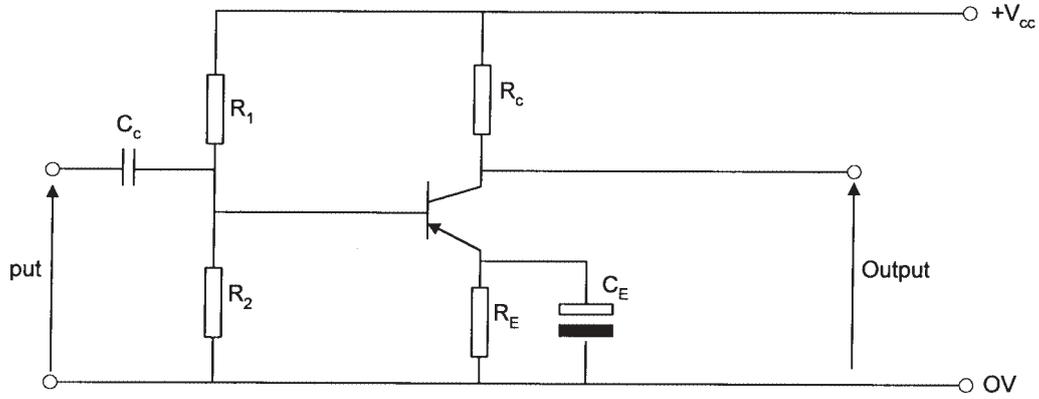
## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ] .

A period of seven days must elapse before an unsuccessful candidate may retake this assignment. An alternative circuit design should be used.

## 6 Assignment documentation

### 6.1 Common emitter transistor amplifier



# 029 Electronics Practical Assignments

## Practical assignment 029/3: Build and Test an Integrated Circuit Power Amplifier

### 1 Competence reference

28.2

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Components: 1 LM380 or equivalent, 2M2 logarithmic potentiometer, 2R7 resistor,  $\Omega$ 3 watt resistor, 470 $\mu$ F electrolytic capacitor, 100nF capacitor, suitable circuit board with combined heat sink as advised by the manufacturers.

Tools: kit of small tools and soldering iron for electronic assembly, resin-cored solder.

Test equipment: 8 $\Omega$  loudspeaker, crystal microphone, dc power supply, multimeter (analogue or digital), audio signal generator, 2-channel oscilloscope and suitable test leads.

Support facilities: drawing and writing materials, LM380 (or equivalent) data sheet, copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to construct the power amplifier in section 6, ensure that the circuit functions correctly, determine the maximum signal levels, mid band gain, overall frequency response, output power and conversion efficiency using appropriate instruments. Record results and show calculations. Candidates have 3 hours to complete this assignment.

Instructors must ensure that health and safety regulations are observed at all times.

### 3 Candidates' instructions

- 3.1 You have 3 hours to complete this assignment. In this assignment you are required to assemble and test a single stage integrated circuit power output amplifier.

Typical Specification:

Power supply $V_{CC}$	20V d.c.	(25V maximum)
Quiescent current		7mA
Voltage gain		50 (34dB)
Input sensitivity		150mV rms
Input resistance		150 k $\Omega$
Maximum input voltage		0.5V
Load resistance		8 $\Omega$
Approximate bandwidth		100kHz

- 3.2 Sketch a circuit diagram of the proposed amplifier. See section 6, Fig 1.
- 3.3 Select components.
- 3.3.1 Choose a suitable amplifier eg LM380, or similar, and refer to the data sheet for the device to establish its specification.
- 3.3.2 Select the supply voltage  $V_{CC}$
- 3.3.3 Select component values if different from the those shown in Fig 1.
- 3.3.4 Draw the circuit diagram showing the component values.
- 3.3.5 Draw up a component list for the proposed design.
- 3.3.6 Design a suitable circuit and component layout for the type of construction to be used, eg strip board or printed circuit board. Take care to include the manufacturers' recommendations for the provision of a heat sink.
- 3.4 Assemble the circuit using appropriate tools.
- 3.5 Inspect the assembled circuit and check for errors. Connect the circuit to a suitable power supply.
- 3.6 Carry out the following performance tests and record all results:
- 3.6.1 Check the supply voltage  $V_{CC}$
- 3.6.2 Connect a loudspeaker across the output terminals and a crystal microphone to the input of the amplifier. Speak into the microphone and vary the setting of the volume control to test that the amplifier provides a satisfactory audio output.

- 3.6.3 Replace the microphone and loudspeaker with a signal generator and 8W resistor respectively. With the input signal frequency set to 1kHz, at a level sufficient to provide a significant output, free from any obvious distortion, measure the input and output voltages using the oscilloscope. Calculate the overall mid band voltage gain.
- 3.6.4 With the connections as in 3.6.3, increase the input voltage to determine the maximum available undistorted output voltage and record the amplitude of the input signal required to achieve this. Calculate from the amplitude of the output voltage, the ac output power delivered to the 8W load.
- 3.6.5 Under conditions of maximum ac output power, measure the dc current taken from the power supply and calculate (a) the dc power supplied to the amplifier and (b) the conversion efficiency of the amplifier.
- 3.6.6 Reset the conditions as at 3.6.3, vary the input signal over a range of frequency and monitor the change in the amplitude of the output voltage on the oscilloscope to determine the bandwidth of the amplifier.
- 3.7 Write a test report to include design calculations, results obtained from the practical measurements and any observations.
- 3.8 Hand in your work to your instructor.

## 4 Marking

- 4.1 Assignment completed in 3 hours. ( )
- 4.2 A circuit diagram of the proposed amplifier sketched. ( )
- 4.3 Components:
- 4.3.1 A suitable amplifier selected [ ]
- 4.3.2 The supply voltage  $V_{CC}$  selected [ ]
- 4.3.3 Component values if different from the those shown in Fig 1 selected [ ]
- 4.3.4 Circuit diagram showing the component values drawn [ ]
- 4.3.5 A component list for the proposed design drawn up [ ]
- 4.3.6 A suitable circuit and component layout for the type of construction to be used designed [ ]
- 4.4 The circuit assembled using appropriate tools. [ ]
- 4.5 The assembled circuit inspected and checked for errors. The circuit connected to a suitable power supply. [ ]
- 4.6 The following performance tests carried out and results recorded:
- 4.6.1 The supply voltage  $V_{CC}$  checked [ ]
- 4.6.2 A loudspeaker connected across the output terminals and a crystal microphone to the input of the amplifier. ( )
- 4.6.3 The microphone and loudspeaker replaced with a signal generator and 8W resistor respectively. With the input signal frequency set to 1kHz, the input and output voltages measured using the oscilloscope. The overall mid band voltage gain calculated. [ ]
- 4.6.4 With the connections as in 4.6.3, the input voltage increased to determine the maximum available undistorted output voltage and the amplitude of the input signal required to achieve this recorded. From the amplitude of the output voltage, the ac output power delivered to the 8W load calculated. [ ]

- 4.6.5 Under conditions of maximum ac output power, measure the dc current taken from the power supply measured and (a) the dc power supplied to the amplifier and (b) the conversion efficiency of the amplifier calculated. [ ]
- 4.6.6 The conditions as at 4.6.3 reset, the input signal over a range of frequency varied and the change in the amplitude of the output voltage on the oscilloscope to determine the bandwidth of the amplifier monitored. [ ]
- 4.7 A test report written. [ ]
- 4.8 Work handed in to the instructor. [ ]

## 5 Assignment completion

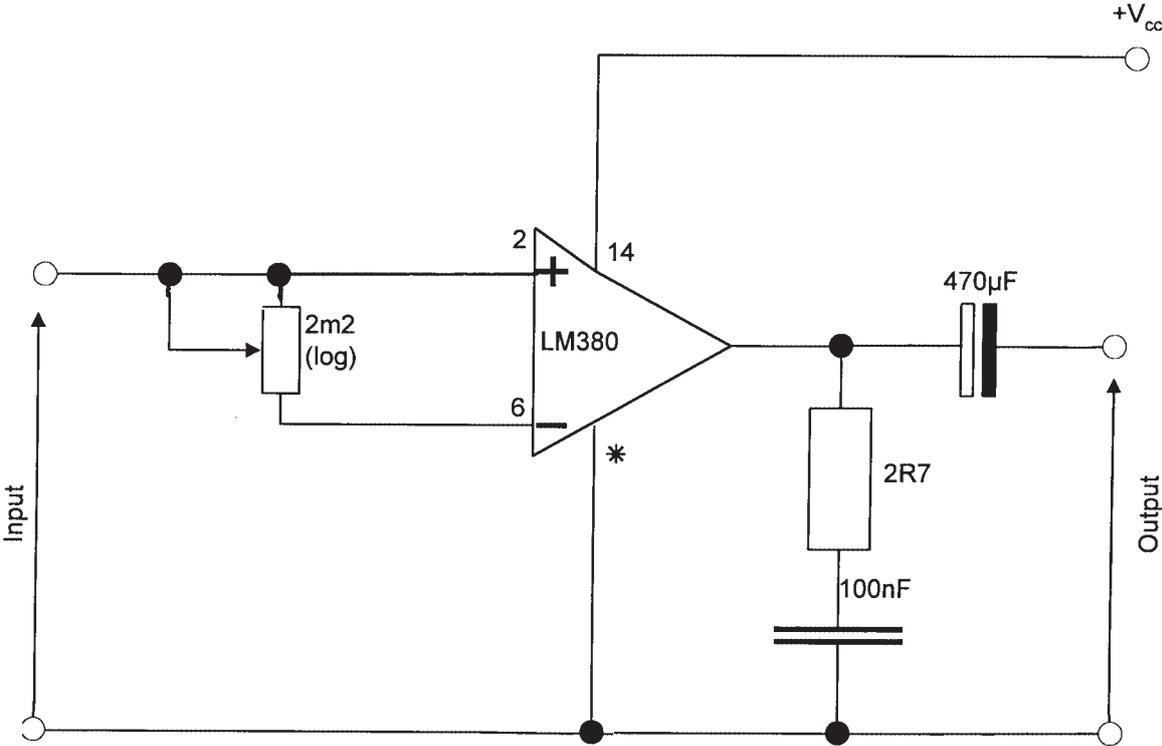
The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ] .

- [ ] A period of several days must elapse before an unsuccessful candidate may retake this assignment.

# 6 Assignment documentation

## 6.1 Integrated circuit power amplifier

Fig 1



# 030 Engineering Project Practical Assignment

## Introduction

The intention of this unit is to provide an opportunity for candidates to solve a realistic engineering problem which requires the application and integration of other modules within the Advanced Diploma programme of study.

The aim of the unit is for candidates to acquire:

- planning, organisation and communication skills
- experience in methods and techniques for product and process improvement
- and to develop personal qualities such as creative ability, imagination, initiative and maturity

## Practical competences

The candidate must be able to do the following:

### Specification and analysis

- 30.1 Select the problem to be solved.
- 30.2 Identify the main elements of the problem.
- 30.3 Define the objectives of the problem.
- 30.4 Prepare a specification of the problem to be solved.
- 30.5 Determine the tasks to be performed to enable the attainment of the objectives.
- 30.6 Organise the tasks chronologically.

### Scheduling and planning

- 30.7 Plan the initial programme for solving the problem.
- 30.8 Estimate the resource requirements for each of the tasks.
- 30.9 Estimate the time needed to complete each task.
- 30.10 Prepare a schedule of work.

### Execution and performance

- 30.11 Obtain the information necessary to solve the problem.
- 30.12 Select equipment or methods of operation to carry out each task.
- 30.13 Perform experimental/investigatory work necessary for the execution of the tasks.

### Evaluation and communication

- 30.14 Evaluate the validity of the results.
- 30.15 Assess the success of the work undertaken.
- 30.16 Make recommendations for further work.

- 30.17 Prepare a project report to specified layout.  
**Layout:** eg title page, summary, contents page, list of figures, tables, symbols as required, introduction, work carried out, evaluation of the results, conclusions as related to the aims of the project, practical recommendations, references and appendices

- 30.18 Ensure that the body of the report includes the following work.  
**Work:** eg relevant background information, clear and precise documentation of the aims of the project, relevant theory, previous work undertaken by other people within the area of activity, the actual work undertaken

- 30.19 Prepare material for an oral presentation.  
**Materials:** eg slides/transparencies, flip charts, audio or video tapes, supporting notes

# 030 Engineering Project Practical Assignment

## Practical assignment 030/1: Solve an Engineering Problem

### 1 Competence reference

30.1-30.19

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Paper, pens, pencils and ruler **or** a computer system running appropriate software (eg word processing, computer aided draughting software) and a printer connected to the system, with paper loaded and set up ready to print.

Manuals for software.

Copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to select and solve individually an engineering problem which can be realistically achieved (see section 6 for suitable suggestions) within 60 hours. The project must be agreed between candidate and instructor and must take into account the amount and level of work required and the resources available. The nature of the work must demonstrate the candidate's ability at advanced diploma level.

The project is generally considered to be a student centred activity. The instructor's main responsibility is to create an effective learning environment. In particular the instructor should check the project objectives, monitor the candidate's progress, advise on project progression, exercise leadership if needed, assist in development of the candidate's skills and knowledge and counsel as appropriate.

Candidates may carry out research and produce materials during the allocated time but the report must be produced at the centre under supervision.

It is recommended that candidates should be allowed adequate time to produce the final report. Candidates may use word processors to produce their report provided they have sufficient word processing skills to do so efficiently.

On completion of the report, candidates are required to carry out an oral presentation of their work to the instructor and peer group. It is envisaged that such a presentation will take between 15-30 minutes.

### 3 Candidates' instructions

- 3.1 You are requested to select and solve a realistic engineering problem. At each stage of this project you must refer to your instructor for continuous guidance and direction. You must keep a log book summarising the work undertaken each week. This log book will be useful in producing the final report. You have 60 hours to complete this assignment.
- 3.2 Select an appropriate project and agree it with your instructor.
- 3.3 Maintain on a regular basis a log book or diary detailing work undertaken.
- 3.4 Identify the main elements of the problem to define the objectives of the project.
- 3.5 Prepare a detailed specification of the problem and organise the tasks to be undertaken chronologically (network diagram or similar).
- 3.6 Plan the initial programme for solving the problem and determine the resource requirements in terms of time, equipment and materials.
- 3.7 Prepare a schedule of the work to be carried out (Gantt chart or similar).
- 3.8 Undertake research in order to obtain the information necessary to solve the problem.
- 3.9 Select equipment or methods of operation to progress the project.
- 3.10 Carry out the work necessary for the completion of the project.
- 3.11 Evaluate the success of the work undertaken and make recommendations for further work.
- 3.12 Prepare a project report using an appropriate format and layout (see section 6.2), which should contain all the work produced in 3.2-3.11 above.
- 3.13 Prepare an oral presentation and present it to your instructor/colleagues.  
**Oral presentation:** eg notes, overhead transparencies
- 3.14 Ensure your name is on the report and hand it in to your instructor.

## 4 Marking

4.1	Project completed in approximately 60 hours.	( )
4.2	Realistic engineering project selected and agreed with instructor.	[ ]
4.3	Log book or diary maintained throughout the project.	[ ]
4.4	The main elements of the problem identified and the objectives defined.	[ ]
4.5	4.5.1 Detailed specification prepared	[ ]
	4.5.2 Tasks to be undertaken organised chronologically	[ ]
	4.5.3 Network diagram or similar produced.	[ ]
4.6	4.6.1 Initial programme planned	[ ]
	4.6.2 Resource requirements determined in terms of time, equipment and materials.	[ ]
4.7	Schedule of work prepared (Gantt chart or similar).	[ ]
4.8	Appropriate research undertaken and relevant information obtained.	[ ]
4.9	Appropriate equipment and methods to progress the work selected.	[ ]
4.10	Necessary work carried out to complete project.	[ ]
4.11	4.11.1 Success of the project evaluated and work assessed.	[ ]
	4.11.2 Recommendations for further work made.	( )
4.12	Project report completed.	[ ]
4.13	Oral presentation prepared and presented.	[ ]
4.14	Report handed in.	[ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] .

Candidates who fail to achieve the requisite number of outcomes should be encouraged to carry out further work in order to complete the assignment satisfactorily.

## 6 Assignment documentation

### 6.1 Choosing a project

The theme of the project is to investigate a particular section of a company and to improve the section in terms of costs or procedures (manufacturing, maintenance, marketing, management). Possible areas for project work are listed below:

- improvement of the efficiency or effectiveness of an existing process
- introduction and commissioning of new plant
- modification of existing equipment to perform new or additional operations
- improvement of maintenance procedures on selected plant or equipment
- introduction of new procedures for measuring, testing and calibrating products or equipment
- standardisation of component parts for product assembly.

### 6.2 Project report writing

The general layout of the project report should be as follows:

title page  
summary  
contents page  
list of figures, list of tables, list of symbols, as required  
Introduction  
work carried out  
evaluation of the results  
conclusions as related to the aims of the project  
practical recommendations  
references and appendices.

The work carried out should include:

relevant background information  
clear and precise documentation of the aims of the project  
relevant theory  
previous work undertaken by other people within the area of activity  
the actual work undertaken

## Introduction

The technician engineer needs to possess an in-depth understanding of the behaviour, performance and processing of traditional and modern engineering materials.

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Steels and heat treatment of steels

- 33.1 Examine the iron-carbon equilibrium diagram and using the inverse lever rule calculate the ratios of different structures produced during various cooling cycles with different carbon content.  
**Structures:** pearlite, martensite, austenite, ferrite, cementite
- 33.2 Explain the difference and identify the importance of the relationship between processing, properties, structures and their uses.
- 33.3 Explain the effects of adding alloying elements to steels.  
**Effects:** increase in strength, increase in hardness, changes in other mechanical/physical properties  
**Elements:** silicon, manganese, nickel, copper, cobalt, chromium, tungsten, molybdenum, vanadium, aluminium
- 33.4 Interpret time-temperature transformation diagrams and continuous cooling transformation diagrams to look at grain structure effects/formation induced by different cooling rates.
- 33.5 Describe the effects of quenching steels in terms of grain structure formation.
- 33.6 Define hardenability.
- 33.7 Describe the procedures for carrying out a Jominy test and interpreting the results.
- 33.8 Explain the heat treatment effects of a range of processes.  
**Processes:** tempering, annealing, martempering, austempering, surface hardening

### Metals and alloys for casting

- 33.9 Describe the different alloys used for casting.  
**Alloys:** aluminium-silicon, magnesium, copper-tin, zinc die casting, cast iron
- 33.10 State the factors to be considered when choosing an alloy for casting.  
**Factors:** melting point, heat treatment effects, applications, weldability, machinability, fluidity

- 33.11 Examine the equilibrium diagram for aluminium-silicon alloy and use the inverse lever rule to calculate the various structures during cooling and identify the mechanical properties achieved.  
**Properties:** tensile strength, ductility, hardness

- 33.12 Explain the factors which influence failure of metals.  
**Factors:** creep, fatigue

### Polymers

- 33.13 Identify the structure of a polymer as a combination of many small molecules to form large molecules resulting in a network chain.  
**Structure:** linear, branched, cross-linked chains, linear amorphous, folded linear, polymer chains
- 33.14 Explain how crystallinity occurs in polymers.
- 33.15 Explain melting temperature with respect to polymeric materials.
- 33.16 Explain the significance of glass transition temperature and state typical values for a range of polymers.  
**Polymers:** polyethylene, polystyrene, polyvinyl chloride, polypropylene
- 33.17 Describe the features of a tensile test on a polymeric material.  
**Features:** non-linear stress/strain relationship, commencement of necking, cold drawn state
- 33.18 Describe internal and external plasticisation and list the change in properties with plasticisers.  
**Properties:** tensile strength, ductility
- 33.19 Compare the mechanical properties of commonly used polymers and explain the effects of temperature.  
**Properties:** tensile strength, ductility
- 33.20 State basic methods of shaping polymers and typical applications.  
**Methods:** moulding, extrusion, vacuum forming, machining
- 33.21 State benefits of manufacturing products and components using polymeric materials and typical applications.  
**Benefits:** range of shapes, final shape, finish achieved, low temperature process
- 33.22 Describe the extrusion process.
- 33.23 Describe the moulding processes.  
Processes: injection, compression, transfer
- 33.24 Describe the processes used for the production of film, sheet and hollow objects.  
**Processes:** slit-die extrusion, blow-film, blow moulding, rotational moulding

- 33.25 Describe thermoforming processes and state typical applications.  
**Processes:** vacuum, pressure, mechanical
- 33.26 Describe the hand lay-up process using glass reinforced plastic (GRP) and state typical applications.
- 33.27 Describe the process of producing component parts using carbon fibre.

#### Finishing processes

- 33.28 Sketch the structure of a grinding wheel and list types of abrasive/grain size and bond.  
**Abrasive:** aluminium oxide, silicon carbide, cubic boron, diamond  
**Bond:** vitrified, silicate, rubber, resinoid, shellac, metallic
- 33.29 Describe a typical abrasive wheel specification, eg A54 M5V, and describe each part.
- 33.30 Describe the cutting action of an abrasive wheel.
- 33.31 Explain the terms 'wheel structure' and 'wheel grade'.
- 33.32 Explain the principle of operation of a range of finishing processes.  
**Processes:** grinding, honing, lapping, super-finishing, polishing, buffing

#### Powder metallurgy

- 33.33 Describe the process stages of powder metallurgy.  
**Stages:** blending/mixing of the powder, compacting, sintering, sizing, impregnation (for porous materials), heat treatment
- 33.34 State the design advantages of powder metallurgy.  
**Advantages:** large quantities, controlled porosity, wide range of metals and alloys

#### Sheet metal processes

- 33.35 Describe the deep drawing process and state common defects and typical applications, eg cans and sinks.
- 33.36 Describe types of presses.  
**Types:** gap frame, press brake, side frame
- 33.37 Describe various tube bending methods.  
**Methods:** stretch, draw, compression
- 33.38 Describe the process of spinning and state applications eg components, cooking utensils.

#### Alternative machining processes

- 33.39 Describe the electrochemical machining (ECM) process, state typical ECM applications, their advantages and disadvantages.  
**Advantages:** use on very hard materials, no component burrs, low tool wear, no distortion, complex geometrical shapes  
**Disadvantages:** high consumption of electricity, cost, workpiece must be an electrical conductor
- 33.40 Describe the electric discharge machining (EDM) process, state typical applications, their advantages and disadvantages.  
**Advantages:** removal of metal from delicate parts, hole drilling at acute angles, machining of hard metals, no distortion, complex geometrical shapes  
**Disadvantages:** tool wear could be a problem due to heat generation, work piece must be an electrical conductor
- 33.41 Describe the electric discharge wire cutting (EDWC) process and state typical applications.

#### Surface texture

- 33.42 State that surface texture is a geometrical property and explain associated terms.  
**Terms:** lay, roughness, waviness
- 33.43 Calculate the surface roughness value given a simple sinusoidal shaped trace.  
**Values:** arithmetic mean value (Ra), root mean square (Rq)
- 33.44 State typical roughness values for standard machining processes.  
**Processes:** rough turning, finish turning, milling, drilling, grinding, honing

# Assessment

## Test specification for written paper Materials and Processes (2565-03-033)

This is a written examination paper lasting two hours with six questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Steels and heat treatment of steels	34
Metals and alloys for casting	
Polymers	34
Finishing processes	16
Powder metallurgy	
Surface texture	
Sheet metal processes	16
Alternative machining processes	

# 034 Advanced Manufacturing and Management

## Introduction

This unit is divided into two parts. The first part is Advanced Manufacturing Systems. The second part is Management of the Manufacturing Process.

## Advanced Manufacturing Systems

This section of the unit focuses on the application of computers in engineering with a particular emphasis on manufacturing.

## Practical competences

The candidate must be able to do the following:

### Computer numerical control (CNC)

- 34.1 Specify operation sequence using operation sheets.
- 34.2 Produce and check a part-program manually.
- 34.3 Produce and check a computer aided part-program.
- 34.4 Prepare, verify, correct errors as necessary, a part-program to produce particular features on a component using a CNC machine (milling machine or lathe).  
**Features:** (milling) internal and external, profiles, straight, angular, circular interpolation, slots, pockets (lathe) external profiles, multi-diameters, chamfers, radii, undercuts, parting off, internal profiles, drilling, reaming, threaded holes

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Computers in engineering

- 34.5 Identify engineering applications that affect the choice of computer systems.  
**Applications:** design, draughting, financial control, inspection, manufacture, projects, process/stock control, testing, quality control
- 34.6 State the benefits and limitations of using a computer aided design system to create design drawings and product models.  
**Benefits:** repeatability, speed, simple editing, reduced storage space, modifications  
**Limitations:** cost of training and equipment
- 34.7 Describe a range of computer terms.  
**Terms:** central processing unit, hardware, software, random access memory (RAM), read only memory (ROM), files, program, network

- 34.8 Describe the main advantages and limitations of a computer system.

**Advantages:** cycle/feed times, reduced production costs, accuracy, best use of resources, information, productivity, quality

**Limitations:** high training and equipment costs

- 34.9 Describe the steps to develop and implement a computer system.

**Steps:** commissioning, investment, forecasting, staffing, leasing, planning, training

### CNC systems

- 34.10 Describe the needs and use of guards and interlocking devices on CNC machines.
- 34.11 State the hazards associated with manual and automatic work and tool changing.
- 34.12 State the problems associated with the removal of waste (swarf) from the working zone.
- 34.13 State procedures for the restarting of CNC machines after emergency shutdown.
- 34.14 Explain the advantages and limitations of CNC machine tools over conventional tools.  
**Advantages:** high repeatability/accuracy, complex shapes  
**Limitations:** high equipment costs, specialist training
- 34.15 Identify the three basic axes of CNC machines.  
**Axes:** x, y, z
- 34.16 Explain the different coordinate systems of CNC machines.  
**Co-ordinates:** absolute, incremental, polar
- 34.17 Describe different types of datum used.  
**Datum:** shift on zero, fixed zero, floating zero
- 34.18 Describe the principle of open loop and closed loop positioning systems used on CNC machines.
- 34.19 Explain the CNC programming terms.  
**Terms:** subroutines, macros
- 34.20 Explain the difference between manual part-programming and computer part-programming techniques.
- 34.21 Compare features of a high level programming language with equivalent machine code instructions.  
**Features:** ease of programming, speed and execution, storage and memory, cost

### Flexible manufacturing systems

- 34.22 Describe typical manufacturing systems.  
**Systems:** jobbing shop, production workshop, stand-alone CNC machine tool, flexible manufacturing cell (FMC), flexible manufacturing systems (FMS), flowline and transfer line
- 34.23 Explain how FMS compares with conventional manufacturing systems.
- 34.24 Explain the basic components of FMS and their integration in the data processing system.
- 34.25 Explain the integration of computer design with manufacturing systems.
- 34.26 Compare the concept of flexible manufacturing cells (FMC) with flexible manufacturing systems (FMS).
- 34.27 List the advantages and limitations of FMC and FMS.  
**Advantages:** high machine tool utilisation, reduced lead times, reduced labour, reduced inventory, reduced work in progress (WIP), parts produced randomly in various batch sizes  
**Limitations:** high cost of system, specialist training
- 34.28 Explain how robots are used within the FMS system.

### Computer aided manufacture (CAM)

- 34.29 State that computer-integrated manufacture (CIM) is the computerised integration of all aspects of design, planning, manufacturing, distribution and management.
- 34.30 Describe the benefits of CIM.  
**Benefits:** lower product cost, shorter product life cycle, rapid response to market demand, quality, improved use of materials and machinery, reduced work-in-progress (WIP), improved employee utilisation
- 34.31 Identify the major stages involved in the use of computers to assist in all aspects of the manufacture of a product.  
**Stages:** design, draughting, processing, ordering, manufacturing, assembly, inspection, testing, storage, transport
- 34.32 Identify the elements of a CAM system.  
**Elements:** machine tools, material handling, tool handling, production control and inspection

### Management of the Manufacturing Process

This section of the unit focuses on planning, quality control, process management and people management.

#### Planning and control

- 34.33 Explain the terms 'production planning' and 'production control' and diagrammatically show the link between them.

- 34.34 Describe the functions of a typical production planning and control system.  
**Functions:** master production schedule (MPS), bill of material (BOM), material requirement planning (MRP), capacity planning (CP), inventory records (IR), purchasing and manufacture

- 34.35 Describe a master production schedule.

- 34.36 Describe the function of a process planning sheet (route card) and identify the information on it.  
**Information:** part number, part name, contract number, material, planning engineer, date, a brief description of the operation performed, equipment, tooling, times

- 34.37 Identify factors related to the economics of component manufacture as opposed to purchasing from other sources (sub-contracted).  
**Factors:** eg reduced costs, loss of control

- 34.38 Explain the goals of 'just in time' (JIT) production.  
**Goals:** eliminate waste (materials, money, lead times, effort), receive supplies just in time to be used to produce parts, produce sub-assemblies just in time to be made into finished products, produce and deliver finished products just in time to be sold

- 34.39 Describe the manufacturing requirements which are essential to achieving the aims of JIT and state the advantages.  
**Requirements:** product design for ease of manufacture, improved production control, multi-skilled workforce, flexible manufacturing, emphasis on quality  
**Advantages:** low inventory, easily corrected faults, lower product cost

#### Quality control

- 34.40 Explain quality in terms of conformance to requirements and fitness for use.
- 34.41 Examine several products and components and analyse the two quality requirements in terms of product feature and freedom from defects.  
**Feature:** design configuration, ease of use, aesthetic appeal, function and performance, reliability, durability, serviceability  
**Defects:** conformance to specification, components within tolerance, no missing parts, no early failures

- 34.42 Explain the term 'process capability.'

- 34.43 Use statistical process control techniques to analyse process variations.

### Process management

- 34.44 State methods of process management.  
**Methods:** critical path analysis (CPA), linear programming
- 34.45 Describe the technique of critical path analysis.
- 34.46 Solve simple problems using critical path techniques.
- 34.47 Describe the technique of linear programming and areas where it is used, eg production schedule.
- 34.48 Explain why it is necessary to forecast product sales.
- 34.49 Describe methods of forecasting.  
**Methods:** moving averages, weighted moving averages, exponential smoothing, exponential smoothing with trend adjustment

### People management

- 34.50 Explain the meaning of 'human resource management'.
- 34.51 Describe the personnel functions within a manufacturing company.  
**Functions:** job design, recruitment and selection, performance management, job evaluation and design of pay structures
- 34.52 Describe the benefits of manpower planning.  
**Benefits:** to review the present levels of manning, to recruit personnel in good time, training programmes can be prepared in advance, the implications of change can be assessed, redundancies can be anticipated or even avoided by redeployment
- 34.53 State various theories of motivation.  
**Theories:** extrinsic, intrinsic, significance of needs/wants, influence of goals, importance of expectations, self efficacy, behavioural theory, social learning theory, attribution theory, role modelling
- 34.54 Describe various leadership styles and give examples of each.  
**Styles:** exploitive authoritative, benevolent authoritative, consultative and participative group management
- 34.55 Explain the need for flexibility in the workplace.  
**Need:** to be competitive, to be adaptive, impact of new technology, new organisation structure
- 34.56 Explain why training is important within any organisation.

- 34.57 Describe methods of training, both on-the-job and off-the-job.  
**Methods:** demonstrations, skill practice, simulation, lectures and talks, discussions, tutorials, audio-visual aids, case studies, role-play exercises, business games, projects
- 34.58 State the health and safety aspects of employment.  
**Aspects:** safety of employees and public is of paramount importance, safety takes place over expediency, every effort made to involve all employees in development and implementation of health and safety procedures, health and safety legislation complied with 'in the spirit' as well as according to the letter of the law

# Assessment

## **Test specification for written paper Advanced Manufacturing and Management (2565-03-034)**

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Computers in engineering	10
CNC systems	20
Flexible manufacturing systems	10
Computer aided manufacture CAM	10
Planning and control	10
Quality control	10
Process management	10
People management	20

# 035 Advanced Manufacturing Engineering Practical Assignments

## Practical assignment 035/1: Operate a CAM System

### 1 Competence reference

34.1, 34.3, 34.4

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

A computer aided draughting system with a mouse and a laser printer.

Computer Aided Manufacture software.

Computer Numerical Control Milling machine.

Materials as specified in drawing AMEE3A (see section 6)

Copy of section 3 and section 6.

#### 2.3 Instructor notes

**Instructors may produce the profile using CAD and save it on disks for candidates to use, or may require candidates to produce their own profiles.**

The aim of this assignment is to produce/use a profile of drawing AMEE3A, transfer it to a CAM package, produce a CNC program and transfer it to a milling machine and machine the profile.

Candidates are allowed 12 hours to complete this assignment and may work alone or in small groups.

Instructors must monitor candidates' work throughout the assignment.

### 3 Candidates' instructions

3.1 You are required to produce/use a profile of drawing AMEE3A, transfer it a CAM package, produce a CNC program transfer it to a milling machine and machine the profile. You are allowed 12 hours to complete this assignment and may work alone or in small groups. Read the instructions carefully and if you do not understand anything then ask your instructor.

Check with your instructor before commencing whether you are required to produce a profile of drawing AMEE3A or use a profile which your instructor has produced and saved on disk.

3.2 Produce/use a profile of drawing AMEE3A.

3.3 Complete the Operation Sheet (see section 6) to include:

3.3.1 machine sequence

3.3.2 tools required

3.3.3 work holding and/or fixtures

3.3.4 calculations including speeds and feeds.

3.4 Tabulate co-ordinates:

3.4.1 draw up a list of co-ordinates using sheet A (see section 6)

3.4.2 show all calculations on sheet B (see section 6).

3.5 3.5.1 Transfer profile of drawing AMEE3A to CAM package.

3.5.2 Produce a draft CNC program and store on disk.

3.6 Plot the programmed tool path.

3.7 Edit the program and produce a listing.

3.8 Transfer the program to a milling machine, set tool offsets and machine the profile.

3.9 Calculate the time to produce component and compare the calculated time with the actual machining time.

3.10 Put your name on your work and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed within 12 hours. ( )
- 4.2 A profile produced/used of drawing AMEE3A using CAD. [ ]
- 4.3 An Operation Sheet produced to include:
  - 4.3.1 machine sequence [ ]
  - 4.3.2 tools required [ ]
  - 4.3.3 work holding and fixtures [ ]
  - 4.3.4 calculations including speeds and feeds. [ ]
- 4.4 Co-ordinates tabulated:
  - 4.4.1 a list of co-ordinates drawn up using sheet A (section 6) [ ]
  - 4.4.2 all calculations shown on sheet B (section 6). [ ]
- 4.5
  - 4.5.1 Profile transferred to CAM package. [ ]
  - 4.5.2 A draft CNC program produced and stored on disk. [ ]
- 4.6 The programmed tool path plotted. [ ]
- 4.7 The program edited and a listing produced. [ ]
- 4.8 The program transferred to a milling machine, tool offsets set and the profile machined. [ ]
- 4.9 The time to produce component calculated and the calculated time compared with the actual machining time. ( )
- 4.10 Work handed in to the instructor. [ ]

## 5 Assignment completion

- ( ) The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ].
- [ ] A period of several days must elapse before an unsuccessful candidate may retake this assignment.



## 6 Assignment documentation

### 6.2 Sheet A – tabulated co-ordinate list

Tabulate the absolute X-Y co-ordinates of points ('B' to 'Y') with respect to the X-Y zero point at 'A'.

Position	X Co-ordinate	Y Co-ordinate
A	0.00	0.00
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
M		
N		
O		
P		
Q		
R		
S		
T		
U		
V		
W		
X		
Y		
Z		

## 6 Assignment documentation

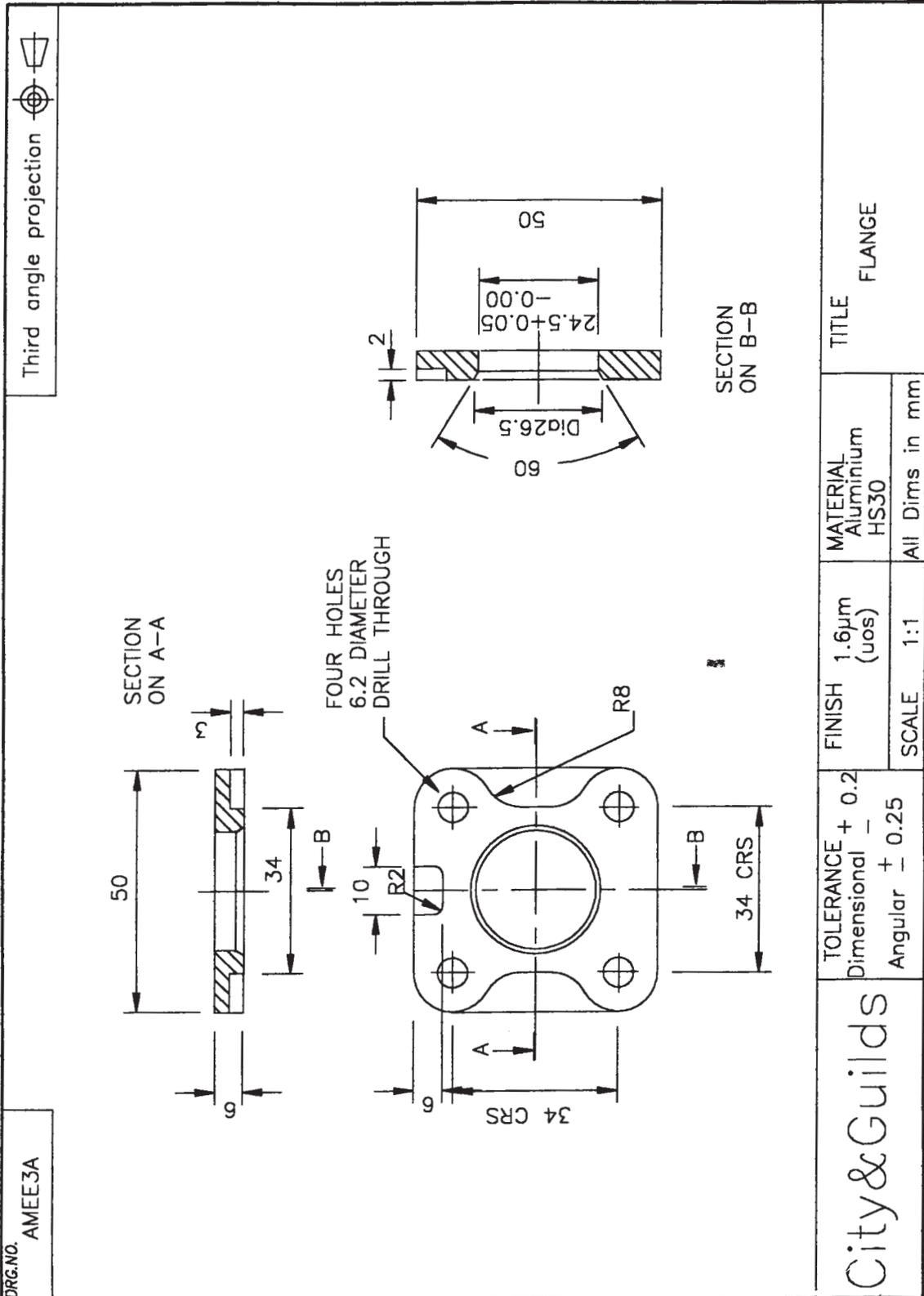
6.3 **Sheet B** – show speeds and feeds calculations here.

For high speed tooling and the material as aluminium take 'S' to be 40 m/min and the feed per tooth to be 0.05 mm.

Operation	Tool No	DIA	'S' m/min	RPM	Feed/min

## 6 Assignment documentation

### 6.4 Drawing AMEE3A



# 035 Advanced Manufacturing Engineering Practical Assignments

## Practical assignment 035/2: Write a Programme Manually to Produce a Spindle

### 1 Competence reference

34.1, 34.2, 34.4

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Computer Numerical Control Milling machine.

Materials as specified in drawing AMEE3B (see section 6).

Copy of section 3 and section 6.

#### 2.3 Instructor notes

The aim of this assignment is to write a CNC programme to produce a spindle (see drawing AMEE3B – section 6) and machine the profile.

Candidates are allowed 8 hours to complete this assignment and may work alone or in small groups.

Instructors must monitor candidates' work throughout the assignment.

### 3 Candidates' instructions

3.1 You are required to write a CNC programme manually to produce a spindle (see drawing AMEE3B – section 6) and machine the profile.

You are allowed 8 hours to complete this assignment and may work alone or in small groups. Study drawing AMEE3B.

3.2 Produce an Operation Sheet (see section 6) to include:

3.2.1 machine sequence

3.2.2 tools required

3.2.3 work holding and fixtures

3.2.4 calculations including speeds and feeds.

3.3 Tabulate co-ordinates:

3.3.1 draw up a list of co-ordinates using sheet A (see section 6)

3.3.2 show all calculations on sheet B (see section 6).

3.4 Write a program to produce the spindle.

3.5 Manually input the programme and edit it.

3.6 Set tool offsets.

3.7 Set the lathe into machine mode and complete a dry run using single step mode.

3.8 Set machine to autcycle mode and machine 'first off' in wax, polystyrene, or any other suitable material.

3.9 Machine actual component.

3.10 Put your name on your work and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 8 hours. ( )
- 4.2 An Operation Sheet produced to include:
  - 4.2.1 machine sequence [ ]
  - 4.2.2 tools required [ ]
  - 4.2.3 work holding and fixtures [ ]
  - 4.2.4 calculations including speeds and feeds. [ ]
- 4.3 Co-ordinates tabulated:
  - 4.3.1 a list of co-ordinates drawn up using sheet A [ ]
  - 4.3.2 all calculations shown on sheet B. [ ]
- 4.4 A program written to produce the spindle. [ ]
- 4.5 The program manually input into the machine and edited. [ ]
- 4.6 Tool offsets set. [ ]
- 4.7 The lathe set into machine mode and a dry run completed using single step mode. [ ]
- 4.8 Machine set to autcycle mode and 'first off' machined in wax, polystyrene, or other suitable material. [ ]
- 4.9 Actual component machined. [ ]
- 4.10 Work handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ] .

A period of several days must elapse before an unsuccessful candidate may retake this assignment.



## 6 Assignment documentation

### 6.2 Sheet A – tabulated co-ordinate list

Tabulate the absolute X-Y co-ordinates of points ('B' to 'Y') with respect to the X-Y zero point at 'A'.

Position	X Co-ordinate	Y Co-ordinate
A	0.00	0.00
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
M		
N		
O		
P		
Q		
R		
S		
T		
U		
V		
W		
X		
Y		
Z		

## 6 Assignment documentation

6.3 **Sheet B** – show speeds and feeds calculations here.

For high speed tooling and the material as aluminium take 'S' to be 40 m/min and the feed per tooth to be 0.05 mm.

Operation	Tool No	DIA	'S' m/min	RPM	Feed/min



# 036 Mechanical Design Practical Assignments

## Introduction

In this unit candidates develop an appreciation of the total design activity and gain knowledge and experience of the design processes as practiced within the engineering industry.

## Practical competences

Candidates must be able to do the following:

### Portfolio production

36.1 Produce a portfolio of suitable reference data for the use of a technician engineer employed in the field of engineering design.

**Reference data:** eg tolerancing (linear and geometric), gears, mechanical fasteners, safety, regulations, bearings and lubrications, material properties, surface protection, material stock sizes, standard beam tables, other relevant standards, data relevant to local needs

### Product specification

36.2 Identify background information to the design requirement.

36.3 Produce a product specification.

**Specification:** environmental, procedures for manufacturing, ergonomic aspects, aesthetic features, performance requirements, legal aspects, safety requirements, maintenance programmes

### Design constraints and requirements

36.4 Identify the design constraints associated with a product specification.

**Design constraints:** cost, balance between design and safety, failsafe or safelife, ease of manufacturing, assembly and maintenance, component loading (magnitude and type)

36.5 Consider possible design solutions.

36.6 Select and evaluate one design solution.

36.7 Develop the selected solution.

36.8 Produce the required drawings for manufacture and assembly.

36.9 Produce evidence of the solution.

**Evidence:** eg model, demonstration unit

36.10 Redesign of existing product in order to achieve an identified function or feature.

**Function or feature:** eg minimum cost, minimum use of material, ease of manufacture and assembly, minimum parts, minimum maintenance, using alternative manufacturing processes

### Pattern drawing for sheet metal components

36.11 Construct curves for intersecting geometrical solids where the axis is at any angle in the same plane or along parallel planes.

**Solids:** cones, right and oblique cones, pyramids, cylinders, prisms, spheres

36.12 Produce pattern drawings for fabricated components using standard methods.

**Methods:** parallel line development, radial line development, triangulation

### Jigs and fixtures

36.13 Explain the purpose and state the application of jigs and fixtures.

36.14 Explain the basic principles of location with reference to the six degrees of freedom.

36.15 Describe and state the application of each of a range of locators and drill bushes.

**Locators:** peg, button, post, vec, adjustable

**Bushes:** fixed, (plain and headed), liner (plain and headed), renewable, slip

36.16 Explain the principles of clamping to achieve the effective restraint of a component.

36.17 Describe typical examples of clamps and clamping devices.

**Typical examples:** eg latch clamps, cam clamps

36.18 Explain the essential design principles associated with jigs and fixtures.

36.19 Produce sketches to show the constructional features of jig and fixture required to accommodate a simple component.

36.20 Design a drill jig and produce associated drawings using a CAD software package.

# 036 Mechanical Design Practical Assignments

## Practical assignment 036/1: Portfolio Production

### 1 Competence reference

36.1

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Portfolio to hold reference material, paper, pens, pencils and ruler. Access to library reference material and supplier catalogues and/or a computer system running appropriate Database software and a printer connected to the system, with paper loaded and set up ready to print.

Manual for Database software.

Copy of Section 3.

#### 2.3 Instructor notes

Candidates have 8 hours in which to prepare a portfolio of suitable information as reference material for an engineering technician involved in design. Candidates should keep these portfolios for use in industry.

It is recommended that instructors should discuss prior to the assignment the range and relevance of each item within the portfolio.

### 3 Candidates' instructions

3.1 You have 8 hours to complete this assignment. You must prepare a portfolio of information suitable as reference material for an engineering technician involved in design.

Data on the items listed below should include where appropriate, available range, operating parameters and sources of supply. It is intended that you will use the portfolio within your profession after completion of the course.

3.2 Prepare a portfolio including data on the following items.

3.2.1 tolerancing (linear and geometric)

3.2.2 gears

3.2.3 mechanical fasteners

3.2.4 safety regulations

3.2.5 bearings and lubrications

3.2.6 material properties

3.2.7 surface protection

3.2.8 material stock sizes

3.2.9 standard beam tables

3.2.10 other relevant standards

3.2.11 materials relevant to local needs.

3.3 Ensure your name is on all your work and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 8 hours. ( )
- 4.2 The portfolio included data on the following items together with range available, operating parameters and sources of supplies:
  - 4.2.1 tolerancing (linear and geometric) [ ]
  - 4.2.2 gears ( )
  - 4.2.3 mechanical fasteners ( )
  - 4.2.4 safety regulations [ ]
  - 4.2.5 bearings and lubrications ( )
  - 4.2.6 material properties ( )
  - 4.2.7 surface protection ( )
  - 4.2.8 material stock sizes ( )
  - 4.2.9 standard beam tables ( )
  - 4.2.10 other relevant standards ( )
  - 4.2.11 materials relevant to local needs ( )
- 4.3 All work handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] and at least 7 of the items marked with a ( ).

Candidates who fail to achieve the requisite number of outcomes should be encouraged to carry out further work in order to complete the assignment satisfactorily.

# 036 Mechanical Design Practical Assignments

## Practical assignment 036/2: Product Specification and Design

### 1 Competence reference

36.2 – 36.9

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Draughting machine or drawing board and Tee square, drawing instruments and writing materials or a computer system providing access to wordprocessing and appropriate Drawing Software and a printer/plotter connected to the system, with paper loaded and set up ready to print.

Software Manuals.

Copy of Section 3.

Portfolio of reference material (produced in Practical Assignment 036/1 Portfolio Production), access to library material or computer database of reference material.

#### 2.3 Instructor notes

Candidates are required to select and agree an appropriate product to design with their instructor (or employer). Candidates may work on the assignments as individuals or in small groups of two or three to produce a product specification and then proceed through the design process in order to produce a satisfactory design outcome. It is important that candidates complete the final report independently and under supervision. The time allowed for this assignment is 40 hours.

It is recommended that instructors produce a design case study which encompasses all the aspects of product specification and the design process and take candidates through the case study prior to their undertaking this assignment.

### 3 Candidates' instructions

You must select and agree a product with your instructor (or employer), produce a product specification and then proceed through the design process to produce a satisfactory design outcome. In order to assist you in making your final report, you should keep a log book and update it regularly. Before commencing this assignment read the instructions through carefully.

- 3.1 The time allowed for this assignment is 40 hours.
- 3.2 Select and agree a suitable product to design with your instructor.
- 3.4 Produce a product specification to include the following information:
  - 3.4.1 Environment.
  - 3.4.2 Procedures for manufacturing
  - 3.4.3 Ergonomic aspects
  - 3.4.4 Aesthetic features
  - 3.4.5 Performance requirements
  - 3.4.6 Legal aspects
  - 3.4.7 Safety requirements
  - 3.4.8 Maintenance programme.
- 3.5 Proceed through the design process documenting every step in order to produce a satisfactory design outcome.
  - 3.5.1 Identify the design constraints associated with the product specification
  - 3.5.2 Consider possible design solutions
  - 3.5.3 Select and evaluate one design solution
  - 3.5.4 Develop the selected solution
  - 3.5.5 Produce the required drawings for manufacture and assembly
  - 3.5.7 Produce evidence of the solution, eg model or demonstration unit.
- 3.6 Produce a report to include all the work you have done in this assignment and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 40 hours. ( )
- 4.2 Appropriate design assignment agreed with the instructor. [ ]
- 4.4 A product specification produced containing the following:
  - 4.4.1 Environment ( )
  - 4.4.2 Procedures for manufacturing ( )
  - 4.4.3 Ergonomic aspects ( )
  - 4.4.4 Aesthetic features ( )
  - 4.4.5 Performance requirements ( )
  - 4.4.6 Legal aspects ( )
  - 4.4.7 Safety requirements ( )
  - 4.4.8 Maintenance programme ( )
- 4.5 The design process undertaken and documented in order to produce a satisfactory design outcome.
  - 4.5.1 Design constraints identified. [ ]
  - 4.5.2 Possible design solutions considered. [ ]
  - 4.5.3 One design solution selected and evaluated. [ ]
  - 4.5.4 The selected solution developed. [ ]
  - 4.5.5 Required drawings produced. [ ]
  - 4.5.7 Evidence produced of the solution. [ ]
- 4.6 A report produced to include all the work done in this assignment and handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] and at least 7 of the items marked with a ( ).

Candidates who fail to achieve the requisite number of outcomes should be encouraged to carry out further work in order to complete the assignment satisfactorily.

# 036 Mechanical Design Practical Assignments

## Practical assignment 036/3: Redesign an Existing Product

### 1 Competence reference

36.10

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Draughting machine or drawing board and Tee square, drawing instruments, A3 drawing paper and writing materials or a computer system providing access to wordprocessing and appropriate drawing software, a printer/plotter connected to the system with paper loaded and set up read to print.

Software Manuals, copy of section 3 and section 6.

Portfolio of reference material (produced in Practical Assignments 036/1 – Portfolio Production), access to library material or computer database of reference material.

#### 2.3 Instructor notes

Candidates are required to read the scenario contained in 6.1 and complete the following tasks: a) explain three factors on which the design consultant's evaluation would have been based;

b) draw three views of the pedestal casting shown in section 6.2, redesigned to be fabricated out of the low-carbon steel.

Candidates have 6 hours to complete this assignment.

### 3 Candidates' instructions

You are required to read the scenario contained in section 6.1, offer explanations and redesign the pedestal casting shown in section 6.2. Before commencing this assignment you are advised to read all the instructions carefully. If you do not understand all the instructions, then ask the instructor.

3.1 This assignment is to be completed in 6 hours.

3.2 Read the scenario contained in 6.1 and explain the factors on which the design consultant's evaluation would have been based.

3.3 Draw to a scale of 1:2 three views, one of which should be sectioned, of the pedestal casting shown in section 6.2 redesigned to be fabricated out of low-carbon steel.

3.4 The redesign is to incorporate the following:

3.4.1 Key dimensions shown to remain the same

3.4.2 Use of flat plate

3.4.3 Reduced material thickness

3.4.4 Elimination of the taper

3.4.5 Correct fabrication and welding techniques

3.5 Identify types of weld using BS or ISO symbols.

3.6 Ensure that the views are well positioned.

3.7 Draw to an acceptable standard of draughtsmanship.

3.8 Ensure your name is on your work and hand it to your instructor.

## 4 Marking

- 4.1 Assignment completed in 6 hours. ( )
- 4.2 Scenario read and an adequate explanation given of factors on which the design consultant's evaluation would have been based [ ]
- 4.3 Three views, one sectioned, drawn to a scale of 1:2 of the pedestal casting redesigned as a low-carbon steel fabrication [ ]
- 4.4 The following incorporated in the redesign:
- 4.4.1 Key dimensions maintained [ ]
  - 4.4.2. Flat plates used [ ]
  - 4.4.3 Material thickness reduced [ ]
  - 4.4.4 Taper eliminated ( )
  - 4.4.5 Correct fabrication and welding techniques used. [ ]
- 4.6 Types of weld identified using BS or ISO symbols ( )
- 4.7 Views well positioned. ( )
- 4.8 Drawing completed to an acceptable standard of draughtsmanship. [ ]
- 4.9 Work handed to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] and at least 2 of the items marked with ( )

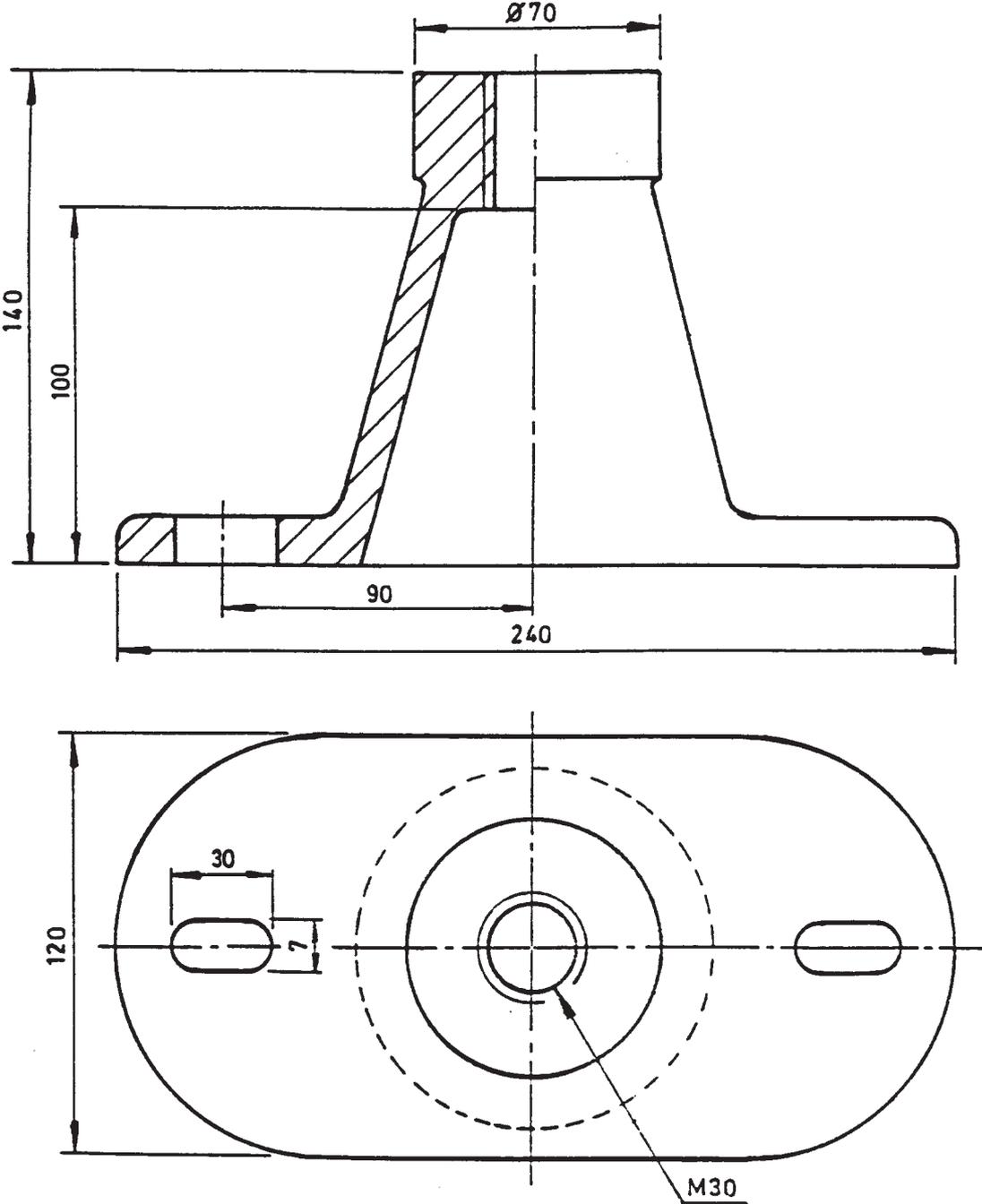
A period of 7 days must elapse before an unsuccessful candidate may retake this assignment.

## 6 Assignment documentation

- 6.1 Scenario
- During the overhaul of two machines at a paper making company, three grey cast iron pedestal castings, each of which form part of a swivel bearing assembly, were found to be fractured and beyond repair.
- On contacting the machine makers, it was established that replacement castings could not be obtained within an acceptable period of time.
- The maintenance manager contacted a local engineering design consultant, who proceeded with an evaluation, and proposed that the pedestal be re-designed to be fabricated out of low-carbon steel in the company's maintenance workshop.

# 6 Assignment documentation

## 6.2 Pedestal Casting



# 036 Mechanical Design Practical Assignments

## Practical assignment 036/4: Pattern Drawing for Sheet Metal Components

### 1 Competence reference

36.11, 36.12

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Draughting machine or drawing board and tee square, drawing instruments and A3 drawing paper.

Copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to produce a pattern drawing for three different sheet metal components within 3 hours.

### 3 Candidates' instructions

3.1 You are required to produce pattern drawings for three different sheet metal components (see section 6). The time allowed for this assignment is 3 hours. You are advised to read all the instructions before starting work. If you do not understand all the instructions, then ask the instructor.

Dimensions shown in section 6 are in millimetres. All construction lines should be clearly shown.

3.2 Hopper and discharge pipe assembly.

Section 6.1 shows the incomplete view of a conical hopper and discharge pipe sheet metal assembly.

3.2.1 Draw the given view to a scale of 1:10

3.2.2 Construct the curve of intersection between the hopper and the discharge pipe.

3.2.3 Draw the curve of intersection.

3.2.4 Construct and draw the developed shape for the half pattern of the hopper.

3.2.5 Draw profile of half pattern.

3.2.6 Construct and draw the developed shape for half pattern of the discharge pipe.

3.2.7 Draw profile of half pattern.

3.2.8 Number, letter and cross-reference construction lines between views.

3.2.9 Ensure that views are well positioned and labelled.

- 3.3 Transition piece
- Section 6.2 shows two views of a transition piece which forms part of a sheet metal ducting assembly.
- 3.3.1 Draw to a scale of 1:10 the two views shown.
- 3.3.2 Construct ellipse accurately.
- 3.3.3 Divide the surface of the transition piece into an appropriate number of triangles.
- 3.3.4 Determine the true lengths of the sides of the triangles.
- 3.3.5 Construct and draw the developed shape for the half pattern of the transition piece.
- 3.3.6 Draw profile of half pattern clearly.
- 3.3.7 Number, letter and cross-reference construction lines between views.
- 3.3.8 Ensure that views are well positioned and labelled.
- 3.4 Draw views to an acceptable standard.
- 3.5 Ensure your name is on your work and hand it to your instructor.

## 4 Marking

- 4.1 Assignment completed in 3 hours. ( )
- 4.2 Hopper and discharge pipe assembly
- 4.2.1 Given view accurately drawn to a scale of 1:10 [ ]
- 4.2.2 Curve of intersection correctly and accurately constructed. [ ]
- 4.2.3 Smooth curve representing the curve of intersection clearly drawn ( )
- 4.2.4 Developed shape for half pattern of hopper correctly and accurately constructed. [ ]
- 4.2.5 Profile of half pattern clearly drawn. ( )
- 4.2.6 Developed shape for half pattern of discharge pipe correctly and accurately constructed. [ ]
- 4.2.7 Profile of half pattern clearly drawn. ( )
- 4.2.8 Construction lines numbered/lettered and cross referenced between views. ( )
- 4.2.9 Views well positioned and labelled. ( )
- 4.3 Transition piece
- 4.3.1 Outline of given views accurately drawn to a scale of 1:10. [ ]
- 4.3.2 Ellipse correctly and accurately constructed. [ ]
- 4.3.3 Appropriate triangulation of surface. [ ]
- 4.3.4 True lengths correctly and accurately determined. [ ]
- 4.3.5 Developed shape for half pattern correctly and accurately constructed. [ ]
- 4.3.6 Profile of half pattern clearly drawn. ( )
- 4.3.7 Construction lines numbered/lettered and cross referenced between views. ( )
- 4.3.8 Views well positioned and labelled. ( )
- 4.4 Acceptable general standard of draughtsmanship. [ ]
- 4.5 Drawings handed in to an instructor. [ ]

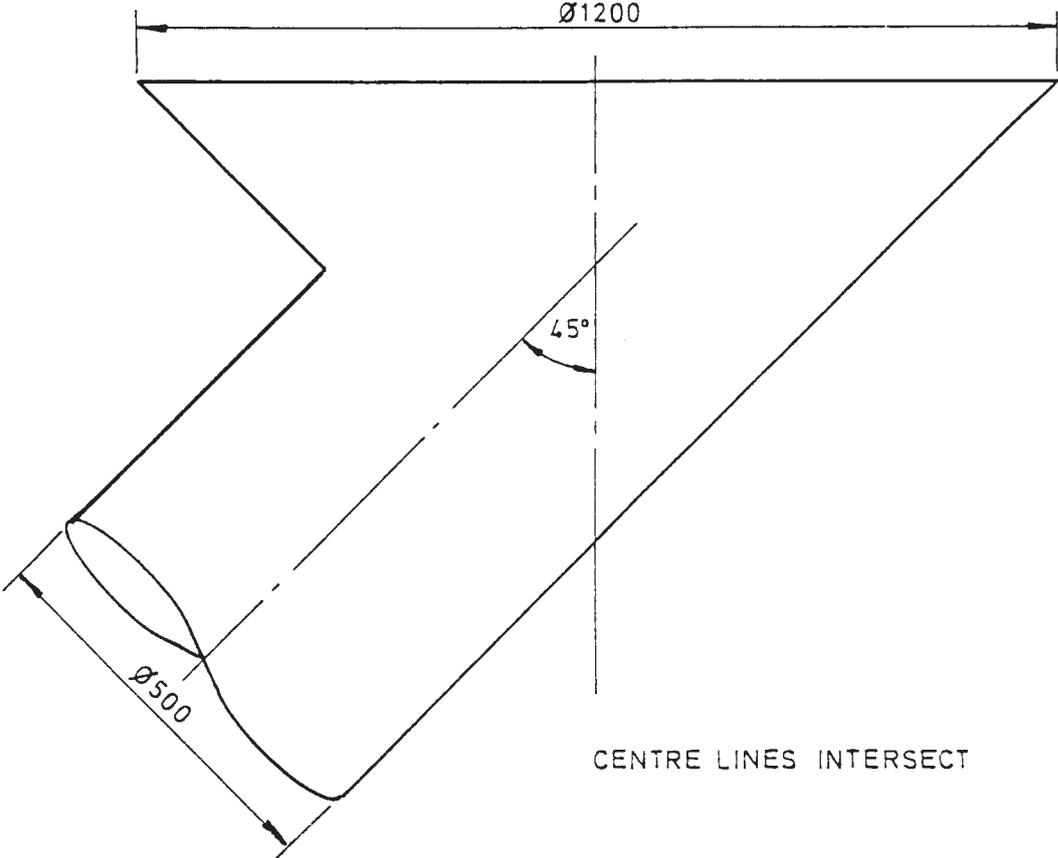
## 5 Assignment completion

The candidate will have satisfactorily completed the assignment if successful in all the items marked with a [ ] and at least 5 items marked ( ).

A period of 7 days must elapse before an unsuccessful candidate may retake this assignment.

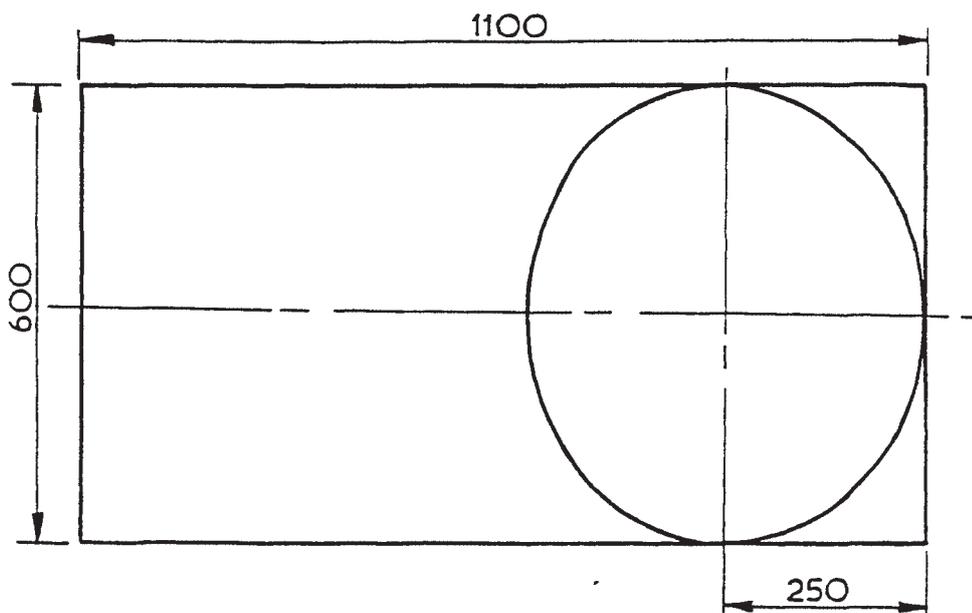
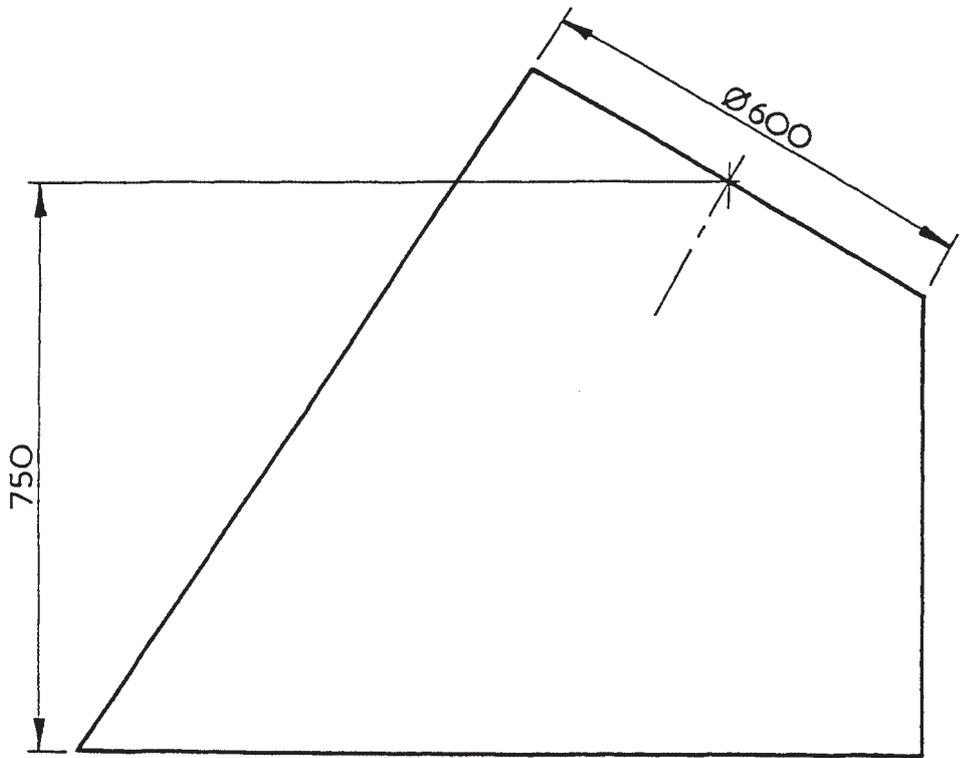
# 6 Assignment documentation

## 6.1 Hopper and discharge pipe assembly



## 6 Assignment documentation

### 6.2 Transition piece



# 036 Mechanical Design

## Practical assignment 036/5: Design and Draw a Drill Jig

### 1 Competence reference

36.19, 36.20

### 2 Preparation

#### 2.1 Location of the test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

A computer system running appropriate drawing software and printer/plotter connected to the system with paper loaded and set up ready to print.

Copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to design and draw using appropriate drawing software a drill jig which will be used to accurately guide an 8mm diameter drill at an angle of 20 degrees to the vertical in the component shown in figure 1. The drilling machine used to drill the hole will be a bench pedestal drilling machine. Candidates have 2 hours to complete this assignment.

### 3 Candidates' instructions

- 3.1 You have 2 hours to complete this assignment. You are required to design a drill jig as enclosed in Section 6.
- 3.2 Produce sketches of at least two design solutions which utilise the datum features of the component part.
- 3.3 Prepare a drawing sheet layout with appropriate border and title block.
- 3.4 Produce three views of the most suitable solution:
  - 3.4.1 a front view
  - 3.4.2 a sectional end view on cutting plane AA
  - 3.4.3 a plan view.
- 3.5 Produce drawing to BS 308 or other ISO standard.
- 3.6 Ensure your name is on your work and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 2 hours. ( )
- 4.2 Sketches of two design solutions produced. ( )
- 4.3 Drawing sheet with appropriate layout produced. ( )
- 4.4 Three views of the most suitable solution produced:
- 4.4.1 a front view ( )
- 4.4.2 a sectional end view on cutting plane AA [ ]
- 4.4.3 a plan view. ( )
- 4.5 Drawing produced to BS 308 or equivalent ISO standard. [ ]
- 4.6 Work handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] and at least three of the items marked with a ( ).

A period of 7 days must elapse before an unsuccessful candidate may retake this assignment.

## 6 Assignment documentation

- 6.1 Figure 1 in section 6 shows a component part which is manufactured in brass. An 8mm diameter hole is required at an angle of 20 degrees to the vertical. Design a drill jig which will clamp the component and accurately guide an 8mm drill. The 10mm wide slot has been previously machined and may be used as a datum location. The drill jig will be used on a bench pedestal drilling machine. The drawing must be drawn to BS 308 or other ISO standard.

You have 2 hours to complete this assignment. The drill jig must be drawn with the component part in location. The following views of the drill jig are required:

- a front view
- a sectional end view on the cutting plane AA
- a plan view.

6 Assignment documentation

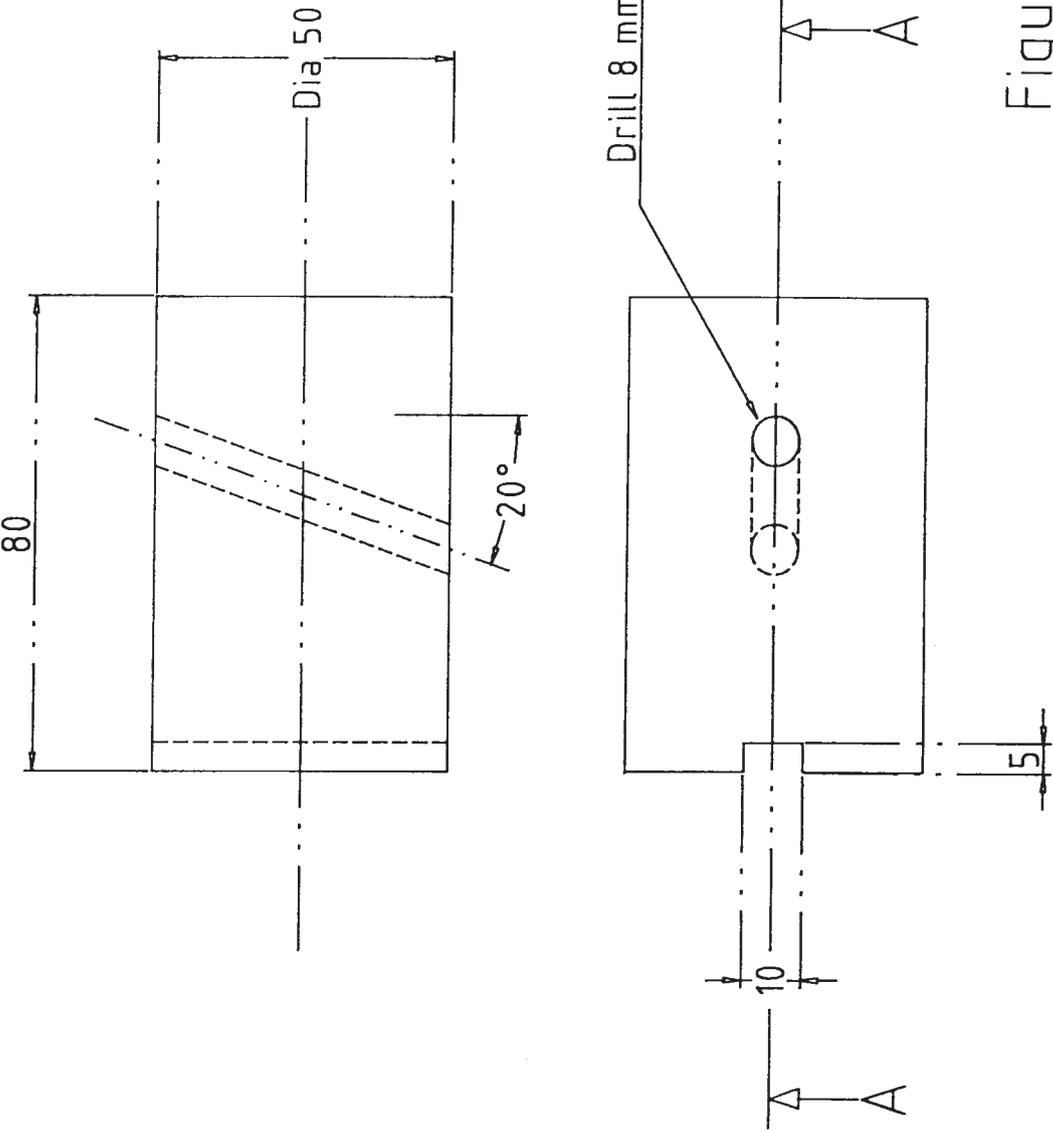


Figure 1

## Introduction

This unit has been designed to build on the skills and knowledge gained from unit 026 Mechanical Principles. The emphasis of the teaching should be on the application of principles, relationships and standard procedures to the solution of realistic engineering problems. Where possible understanding should be developed through associated laboratory work.

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Stress and strain

- 37.1 Calculate the second moment of area about the neutral axis for complex and un-symmetrical sections using the principle of moments and the theorem of parallel axis.  
**Sections:** T, I with unequal flanges, channel, built-up
- 37.2 Identify components that are subjected to combine bending and direct load, and sketch the stress distribution diagram at a section normal to the axis of the component.
- 37.3 Solve problems involving components subjected to combined bending and direct load.
- 37.4 Define Poisson's ( $\nu$ ) ratio and explain the strain relationships for two and three-dimensional stress systems.
- 37.5 Explain the term 'volumetric strain' and define bulk modulus.
- 37.6 State the relationships between the elastic constants.  
**Relationships:**  $E = 2G(1 + \nu)$ ,  $E = 3K(1 - 2\nu)$
- 37.7 Solve problems involving dimensional and volumetric changes in stressed components.

### Beams

- 37.8 Explain the term 'section modulus ( $Z$ )' and the relationship  $Z = I/\Sigma$
- 37.9 Calculate the minimum permissible section modulus for loaded simply supported and cantilever beams, and use universal beam tables or databases to select suitable beam sections.  
**Loading:** point, uniformly distributed, combined
- 37.10 Explain the relationship,  $\frac{d^2y}{dx^2} = \frac{M}{EI}$  and apply the integration method to the four standard cases, to obtain deflection relationships.  
**Cases:** simply supported beam with (i) central point load and (ii) uniformly distributed load, cantilever with (i) point end load (ii) uniformly distributed load

- 37.11 Use the principle of superposition to solve problems involving the deflection of beams.
- 37.12 Apply Macaulay's method to solve problems involving simply supported beams with asymmetrical loading.  
**Loading:** point, uniformly distributed, combined

### Mechanisms

- 37.13 Explain the relative velocity and acceleration of two points on a rigid link.
- 37.14 Construct velocity and acceleration diagrams to solve problems involving mechanisms.  
**Mechanisms:** slider and crank, four bar chain, quick return

### Gear drives

- 37.15 Define the terms associated with gear teeth and describe an involute tooth form.  
**Terms:** pitch circle diameter, circular pitch, diametral pitch, module, centre distance
- 37.16 Describe gear trains and solve problems involving gear ratio and input, output and holding torques.  
**Gear trains:** simple, compound, epicyclic
- 37.17 Apply Newton's second law to problems involving the acceleration of geared systems.

### Bearings

- 37.18 Define viscosity and explain that for thin film lubrication:
- $$\text{viscous stress} = \frac{\text{viscosity} \times \text{velocity}}{\text{thickness}}$$
- 37.19 Use the relationship,  $\text{viscous force} = \text{viscous stress} \times \text{area}$ , to solve problems involving the power loss in cylindrical or journal bearings.

### Friction drives

- 37.20 Describe friction clutches and use standard relationships between torque, coefficient of friction, force on pressure plate, dimensions and configuration to solve problems involving power transmission.  
**Clutches:** plate, cone, centrifugal
- 37.21 Describe flat belt and V-belt drives and use standard relationships between belt tensions, coefficient of friction, angle of lap and groove angle to solve problems involving the maximum power that may be transmitted.

### Flywheel

- 37.22 Describe turning moment diagrams.  
**Diagrams:** reciprocating engines, punching machines, crank presses
- 37.23 Explain the term 'fluctuation of energy' and state the relationship, coefficient of fluctuation of speed = fluctuation of speed/ mean speed



# Assessment

## Test Specification for Written Question Paper Applied Mechanics (2565-03-037)

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

Topic	Approximate % examination weighting
Stress and strain Beams	20
Mechanisms Gear drives	20
Bearings Friction drives Flywheel	20
Balancing Mechanical vibrations	20
Fluid statics Fluid dynamics	20

# 038 Plant Technology and Maintenance Procedures

## Introduction

This unit is divided into two parts. The first part is Advanced Plant Technology and the second part is Plant Maintenance Procedures.

## Advanced Plant Technology

This section of the unit is designed to give candidates a knowledge of the construction and operation of plant, the related theoretical principles and performance calculation procedures. Health and safety procedures must be emphasised throughout this unit

## Practical competences

The candidates must be able to do the following:

- 38.1 Draw line diagrams of a given steam generation and power plant.
- 38.2 Identify the components and state their function and principles of operation.
- 38.3 Draw line diagrams to show the layout of a given refrigerated building and the details of vapour compression refrigeration units.
- 38.4 Calculate coefficient performances, refrigeration effecting and refrigerating load for a vapour compression refrigerator.

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Combustion

- 38.5 Calculate the percentage analysis by mass of 'wet' and 'dry' products of the complete combustion of solid and liquid fuels where excess air is supplied.
- 38.6 Explain why it is usual to quote only the 'dry' products.
- 38.7 Calculate the percentage analysis by volume of 'wet' and 'dry' products of a gaseous fuel where excess air is supplied.
- 38.8 Define higher and lower calorific value.
- 38.9 Calculate the higher calorific value of a fuel given the calorific value of the constituent parts.
- 38.10 Define the properties of a liquid fuel.  
**Properties:** flash point, ignition temperature, octane and cetane number

### Refrigeration

- 38.11 State the main elements of a vapour compression refrigerator and explain with the aid of a block diagram its operation.  
**Elements:** compressor, condenser, throttle valve and evaporator
- 38.12 Sketch the cycle of operation of a vapour compression refrigerator on a pressure/enthalpy diagram and describe the stages.  
**Stages:** compression, condensation, expansion, evaporation
- 38.13 Explain that an isentropic process is a constant temperature entropy process.
- 38.14 State that for ideal conditions the compression of the refrigerant in a vapour compression refrigerator is isentropic.
- 38.15 Solve problems to find the temperature of the refrigerant after isentropic compression.
- 38.16 Define a range of refrigeration terms.  
**Terms:** coefficient of performance (COP), refrigerating effect, refrigerating load (tonnes of refrigerant)
- 38.17 Explain the effect on refrigeration of undercooling after condensation and superheating after compression.
- 38.18 Solve problems on a range of terms using tables of thermodynamic and transport properties of fluids (eg Mayhew and Rogers).  
**Terms:** coefficient of performance (COP), refrigerating effect, refrigerating load
- 38.19 State the main elements of a vapour absorption refrigerator and explain with the aid of a block diagram its operation.  
**Elements:** pump, heater element, throttle valve, evaporator
- 38.20 State the properties of commonly used refrigerants giving their advantages and disadvantages.  
**Refrigerants:** ammonia, refrigerant 409A (409A replaces Freon 12 and has similar characteristics)
- 38.21 Describe the methods of leak detection for refrigerants.  
**Refrigerants:** ammonia, refrigerant 409 A (409 A replaces Freon 12 and has similar characteristics)
- 38.22 Explain what is meant by the terms 'direct' and 'indirect' refrigeration.
- 38.23 Explain how a control system operates in a refrigerator.

38.24 Demonstrate a knowledge of safe procedure and working practices in a refrigeration plant.

**Safe procedures:** gas masks, check for leaks, permit to work, pressure vessels, non-spark tools.

**Working procedures:** purifying system, correct labelling of refrigerants, disposal of refrigerants, refrigerant recharging

### Thermal insulations of buildings and furnaces

38.25 Explain the need for the insulation of buildings and furnaces.

38.26 Describe methods of insulating buildings, furnaces and cold rooms.

**Methods:** cladding, fire bricks, refractory rendering, cork panelling

38.27 Explain the meaning of the term 'heat transfer coefficient' (U value) and recognise that all materials have specific values.

38.28 Evaluate the overall U value for a composite wall given the individual values of each layer.

38.29 Calculate total heat transfer from the buildings, furnaces and cold rooms given all relevant information.

**Information:** dimensions, materials, U values, surface temperatures

38.30 Solve problems in cost saving after insulation has been carried out.

### Steam generation

38.31 Derive an expression for the equivalent evaporation of a steam generating plant 'from and at 100°C' and state that generators are rated as actual evaporation and equivalent evaporation.

38.32 Solve problems involving steam generation, plant efficiency, equivalent evaporation and the amount of heat transferred in the economiser, evaporator, superheater.

38.33 Draw up an energy balance on a percentage basis for a steam generating plant, consisting of an economiser, evaporator and super heater.

38.34 Explain where energy losses occur in the plant and how these losses can be minimised.

**Losses:** flue gases, radiation, incomplete combustion, air ingress

38.35 State the factors affecting the thermal efficiency of steam generation.

**Factors:** air ingress, poor firing equipment, fouling of heat transfer surfaces, excess air

38.36 State reasons for controlling the upper and lower limits of feedwater temperature flowing through an economiser.

38.37 Calculate outlet temperatures of feedwater from economisers given inlet temperatures and flue gas conditions.

38.38 Explain briefly external methods of water treatment.

**Methods:** sedimentation, filtration, precipitation softening, ion exchange system

### Steam power plant

38.39 Explain the difference between steam for process and steam for power.

38.40 Explain the use of back pressure, pass out and condensing turbines for supplying both power and process steam.

38.41 Explain the use of a reducing valve and de-superheater to by-pass a turbine when a required steam demand has to be met for process work.

38.42 Explain the reasons why the largest heat loss occurs in the condenser.

38.43 Carry out calculations to show that the largest heat loss occurs in the condenser.

38.44 Explain how a vacuum is produced and maintained in a condenser.

38.45 Explain the need for cleaning condenser tubes on a regular basis.

38.46 State the effects of cooling water leakage into the condensate.

38.47 Solve problems involving rate of flow of cooling water in a condenser given steam conditions and flow rates.

38.48 Explain why throttling is a wasteful process and the turbine can be used to reduce steam pressure for process work.

38.49 Explain why most heat exchangers are contra-flow.

38.50 Explain why a low exhaust pressure is important if a turbine is to develop maximum power.

### Steam utilisation

38.51 Explain what is meant by the term 'flash steam' and state that flash steam may be generated from high pressure and high temperature condensate.

38.52 Calculate the quantity of 'flash steam' produced from given values.

**Values:** pressures, temperatures, flow rates

38.53 Describe the construction of a typical 'flash steam' vessel.

38.54 Describe the application of thermostatic control to items in common use.

**Items:** heating calorifiers, constant temperature heaters

38.55 Describe the harmful effect of air in a steam plant and explain how air enters the system and how it can be removed.

### Prime movers

38.56 State the various types of prime movers.

**Types:** electric motor, CI and SI engines, steam, gas turbines

38.57 State the factors that should be considered when selecting a prime mover.

**Factors:** cost, power requirement, availability, energy source, mass, efficiency, maintenance requirement, environment

38.58 Describe the need for various services to prime movers.

38.59 Select a prime mover for a given purpose and justify the choices made.

38.60 Explain that some prime movers are more suitable for stand-by emergency equipment.

### SI and CI engines

38.61 Explain engine performance criteria.

**Criteria:** indicated and brake power, mechanical efficiency, thermal efficiency, specific fuel consumption

38.62 Solve problems involving engine performance criteria.

38.63 Draw up a heat balance on a percentage basis from given test data.

38.64 Draw a graph of brake power against mechanical efficiency, thermal efficiency and specific fuel consumption to show the characteristics of both types of engines under full-load conditions and compare the results.

### Gas turbines

38.65 Explain the advantages limitations and applications of an open circuit gas turbine plant.

**Advantages:** high power outputs, utilisation of hot exhaust gases, fast start-up time to fuel load

**Limitations:** low thermal efficiency, automatic devices required because of high temperatures and speed

**Applications:** aircraft engines, stand-by plant, marine propulsion

38.66 Explain the difference between an open circuit and closed circuit system and give advantages of the closed system.

38.67 Explain with the aid of a p/v diagram the cycle of operation for a gas turbine.

### Steam turbines

38.68 Explain the basic principle of operation of steam turbines.

38.69 State that turbines are classified as 'impulse' and 'reaction' and explain their differences.

38.70 Explain why it is essential to use superheated steam for turbine operations.

38.71 Describe pressure and velocity compounding.

38.72 Describe the advantages, limitations and applications of steam turbines.

**Advantages:** low pressure steam can be used, high power for comparatively small units, flow process

**Limitations:** low thermal efficiency compared with CI engines

**Applications:** generation of electrical power

38.73 Solve simple problems in determining power output thermal efficiencies.

### Electric motors

38.74 Explain the basic principles of operation of electric motors.

38.75 Explain the advantages, limitations and applications of electric motors.

**Electric motors:** dc motors (shunt and series), ac motors (induction and synchronous)

38.76 Explain why the overall efficiency of a motor from generation to output is about 30 percent.

38.77 Solve problems for power outputs in single and three phase induction motors given voltage, current and power factor.

38.78 Solve problems involving power factor correction when using capacitors or synchronous motors.

### Illumination

38.79 Explain a range of illumination terms and units used in lighting design.

**Terms:** luminous flux, luminous intensity, illuminance, luminance, luminosity, glare, efficacy, reflectance, colour rendering

**Units:** lumen, candela, lux

38.80 Demonstrate a knowledge of the use of an illuminance meter and a luminance meter.

38.81 Describe, with the aid of diagrams, the main constructional features of a range of lamps.

**Lamps:** filament, fluorescent, sodium

38.82 Compare a range of lamps in the following terms.

**Terms:** efficacy, rated life, colour rendering, main applications, cost

- 38.83 Explain how stroboscopic and flicker effects from discharge lamps may be reduced.
- 38.84 Select from standard codes suitable illuminance levels for particular plant situations.
- 38.85 Define the terms 'utilisation factor' (UF) and 'maintenance factor' (MF).
- 38.86 Explain the 'lumen' method of design and calculate the number of lamps required for a particular situation.

#### **Plant Maintenance Procedures**

This section focuses on health and safety codes of practice, maintenance systems, maintenance control and fault diagnosis. Reference should be made to BS 3811:1984 'Maintenance Management Terms in Terotechnology' and BS 4778:1991 'Quality Vocabulary' or the corresponding International Standards.

## **Knowledge requirements**

Instructors must ensure that candidates are able to:

#### **Health and safety**

- 38.87 Explain the classification of fires and for each class state the type of extinguisher that should be used.  
**Classes:** A, B, C, D
- 38.88 Describe permit-to-work procedures.  
**Procedures:** situations, types, documentation, monitoring
- 38.89 Explain the main requirements of statutory codes of safety.  
**Codes:** guarding of machinery, use of abrasive wheels, chemical hazards

### Maintenance systems

- 38.90 Explain the aims of maintenance management and the objectives of a maintenance organisation.
- 38.91 Describe maintenance systems and draw a 'family tree' to show how they are grouped.  
**Systems:** planned, unplanned, preventive, scheduled, condition-based, corrective (including emergency)
- 38.92 Make comparisons between planned and unplanned maintenance.  
**Comparisons:** materials, lost production, labour
- 38.93 Describe the resources required to operate a preventive maintenance programme effectively.  
**Resources:** suitable workshop and equipment, tools, test equipment, spares, materials, trained personnel, reference data
- 38.94 Describe the steps to be taken before preventive maintenance is commenced, and the procedures that should be implemented on completion.
- 38.95 Describe the activities that are included in a scheduled maintenance programme.  
**Activities:** cleaning, lubrication, replenishment, adjustment, testing, inspection, reconditioning, replacement of 'lifted' components, inclusion of modifications
- 38.96 Write typical maintenance schedules for items of plant.  
**Items:** prime mover, compressor, machine tool
- 38.97 Explain the purpose of condition monitoring and describe typical methods used.  
**Methods:** recording, (temperature, vibration, noise), spectrographic oil analysis, particle retrieval, relative displacement measurement)
- 38.98 Explain the purpose of corrective maintenance and distinguish between the terms used.  
**Terms:** symptoms, fault description, diagnosis of the cause

### Maintenance control

- 38.99 Describe the application of a computerised system for maintenance data processing.  
**Application:** tasks undertaken, organisational arrangements, effects on other sections of the factory, cost effectiveness
- 38.100 Explain the concept and importance of reliability and the consequences of unreliability in both hardware and software systems.
- 38.101 Explain reliability characteristics and the concept of failure classification.  
**Characteristics:** reliability, mean life, failure rate, mean time to failure (MTTF), mean time between failures (MTBF)

- 38.102 Solve problems relating to characteristics in 38.101.
- 38.103 Distinguish between the terms 'fault' and 'failure'.
- 38.104 Draw and interpret typical failure-time 'bathtub' curves.
- 38.105 Explain the concept of availability and maintainability.
- 38.106 Describe the effect of obtaining improved reliability and maintainability.

### Fault diagnosis

- 38.107 Explain the basic principles of determining the prime cause of a fault.  
**Principles:** knowledge and understanding, experience and expertise, step-by-step strategy
- 38.108 Describe the stages of logical fault finding and rectification.  
**Stages:** collection and collation of defect data, plant information and resources, analysis of evidence, use of fault location techniques, diagnosis and classification of cause, rectification of fault (repair or replace), functional checks
- 38.109 Describe defect recording procedures.  
**Procedures:** completion of standardised report, recommendations, distribution to appropriate departments

# Assessment

## Test specification for written question paper Plant Technology and Maintenance Procedures (2565-03-038)

This is a written examination paper lasting three hours with 10 questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Combustion	5
Refrigeration	15
Thermal insulation	5
Steam generation	} 20
Steam power plant	
Steam utilisation	
Prime movers	} 20
SI and CI engines	
Gas turbines	
Steam turbines	
Electric motors	
Illumination	5
Health and safety	} 20
Maintenance systems	
Maintenance control	
Fault diagnosis	10

# 039 Advanced Plant Practical Assignments

## Practical assignment 039/1: Steam Generation and Power Plant

### 1 Competence reference

38.1, 38.2

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Writing materials, drawing board and Tee square or draughting machine or a computer system running appropriate software (eg word processing, computer aided drafting software) and a printer connected to the system, with paper loaded and set up ready to print.

Manuals for software.

Copy of section 3 and section 6.

#### 2.3 Instructor notes

In this assignment candidates are required to write a report on a steam generation and power plant (see section 6).

Candidates should be encouraged to use the computer facilities to complete this assignment. The time allocated is 6 hours.

### 3 Candidates' instructions

3.1 The time allowed for this assignment is 6 hours. The assignment is based on steam generation and power plant. The details are shown in section 6.

You are advised to read all the instructions before commencing work. If you do not understand all the instructions then please ask the instructor.

3.2 Draw a line diagram of the plant showing steam, condensate pipelines and traps.

Include in the line diagram all necessary fittings and equipment for the safe and efficient running of the plant

3.3 On the line diagram, show how the high pressure steam could be utilised to heat up the chemicals when the turbine is shut down for maintenance.

3.4 Explain using the diagram how the chemical in heat exchanger B could be kept at a constant temperature during transit.

3.5 Name the type of steam trap which should be used to accommodate the heavy condensate load produced in heat exchangers C and D.

3.6 Describe a method of lifting the condensate efficiently to the storage tank.

3.7 Produce a brief report and include the line diagram and the information produced in 3.3 – 3.6

3.8 Ensure that your name is on the report and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 6 hours. ( )
- 4.2 A line diagram of the plant produced showing steam, condensate pipelines, traps and all necessary fittings and equipment for the safe and efficient running of the plant. [ ]
- 4.3 Utilisation of the high pressure steam to heat up the chemicals when the turbine is shut down for maintenance shown on the line diagram. [ ]
- 4.4 How the chemical in heat exchanger B could be kept at a constant temperature during transit explained. [ ]
- 4.5 The type of steam trap which should be used to accommodate the heavy condensate load produced in heat exchangers C and D named. [ ]
- 4.6 Efficient lifting of this condensate described. [ ]
- 4.7 Report including diagram and information relating to 4.3 – 4.6 produced. [ ]
- 4.8 Report handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] .

Candidates who fail to achieve the requisite number of outcomes should repeat the assignment using an alternative set of data.

## 6 Assignment documentation

Steam produced by two in-line boilers is used for electrical power production and process heating. The boilers supply steam at 25 bar and 350°C to a back pressure turbine which exhausts steam at 9 bar with a dryness fraction of 0.95. This exhaust steam is transported through a pipeline 150m long to heat up various chemicals passing through four separate heat exchangers A, B, C and D.

From heat exchanger A, the condensate produced is discharged into a flash steam vessel which is at 3 bar. The flash steam is then used for space heating in another part of the plant. The condensate from the flash vessel is discharged together with the condensate from the other heat exchangers into a storage tank 2m above the exchanges where it is indirectly cooled. It is then returned to the power plant as boiler feedwater.

A chemical with a low specific heat capacity has to be pumped from heat exchanger B a distance of 100 m and has to be kept at a constant temperature whilst being moved. The masses of the chemicals passing through the heat exchangers C and D can vary immensely over any 24-hour period, producing a heavy condensate load at times.

# 039 Advanced Plant Practical Assignments

## Practical assignment 039/2: Calculate heat transference and refrigeration requirements to keep a building at a constant temperature

### 1 Competence reference

38.3, 38.4

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Writing materials, drawing board and Tee square **or** draughting machine **or** a computer system running appropriate software (eg word processing, computer aided draughting software) and a printer connected to the system, loaded and ready to print.

Tables of Thermodynamic and Transport Properties of Fluids.

Copy of section 3 and section 6.

Formulae sheet showing details of formulae and relationships.

#### 2.3 Instructor notes

In this assignment candidates are required to draw and label a refrigerated warehouse (see section 6) and calculate the energy transfer, the capacity of the refrigeration unit and its coefficient of performance.

Instructors must provide candidates with details of formulae and relationships required (Formulae sheet). Instructors must also check candidates' calculations at each stage.

Candidates should be encouraged to use the computer facilities to complete this assignment. The time allocated for this assignment is 9 hours.

### 3 Candidates' instructions

3.1 The time allowed for this assignment is 9 hours. You are required to produce a report on a refrigerated warehouse, see details in section 6. You may use a wordprocessor and computer aided draughting software to carry out the assignment. Make sure you have a copy of the Formulae sheet and that you check your calculations with your instructor at each stage.

You are advised to read all the instructions before commencing work. If you do not understand all the instructions then please ask the instructor.

3.2 Draw a labelled line diagram showing the layout of the warehouse and refrigeration unit within its building. The diagram should show the evaporator, condenser, throttler, compressor and how the brine is pumped around the warehouse using a manifold system to give a uniform distribution.

3.3 Calculate using the relevant equations (see Formulae sheet) and the given data:

3.3.1 the energy transferred per minute through the fabric of the warehouse.

3.3.2 the minimum capacity required of the refrigeration unit in tonnes of refrigeration.

3.3.3 the Coefficient of Performance (COP) of the refrigerator.

3.4 Produce a brief report on the refrigerated warehouse and include the line diagram with details of calculations performed and final results obtained.

3.5 Hand in the report to the instructor.

## 4 Marking

- 4.1 Assignment completed in 9 hours. ( )
- 4.2 A line diagram showing all the necessary features of the building and correctly labelled evaporator, condenser, throttler and compressor. The diagram must show how the brine is chilled and the brine is pumped around the warehouse using a manifold system to give a uniform distribution. [ ]
- 4.3 The following calculations carried out:
- 4.3.1 The energy transferred per minute through the fabric of the warehouse correctly calculated. [ ]
- 4.3.2 The minimum capacity required for the refrigeration unit in tonnes of refrigeration. [ ]
- 4.3.3 The Coefficient of Performance (COP) correctly calculated. [ ]
- 4.4 Report produced which includes line diagrams with details of calculations performed and final results obtained. [ ]
- 4.5 Work handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] .

Candidates who fail to achieve the requisite number of outcomes should repeat the assignment using an alternative set of data.

## 6 Assignment documentation

A refrigerated warehouse has internal dimensions of width 12m, length 50m and height of 5m to the eaves. The centre ridge of the roof runs the full length of the building and the roof has a pitch of 30°. The warehouse is to be kept at 2°C by an indirect refrigeration system using brine to circulate around pipe fixed to the walls. The refrigeration unit is to be installed in a building adjacent to it and the primary refrigerant used is ammonia.

There are 2 air changes per hour, due to produce being transported in and out of the warehouse, and the outside air temperature is on average 15°C. (Underfloor temperature to be taken as the same as outside).

Necessary data.

Heat transfer coefficients	W/m <sup>2</sup> K
Insulated walls and ceiling	0.06
Concrete floor	0.4
Doors to be considered as walls	
Density of air	1.2 kg/m <sup>3</sup>
Specific heat capacity of air	1.01 kJ/kg K
1 tonne of refrigeration	233 kJ/min
Pressure range of refrigerant	1.447 bar to 5.346 bar
Temperature after isentropic compression	56°C
Refrigerant undercooled	4°C
Refrigerant leaves evaporator dry saturated	
Efficiency of brine chiller	90%

# 040 Plant Hydraulics and Pneumatics

## Introduction

This unit is divided into two parts, Plant Hydraulics and Plant Pneumatics. It is recommended that the teaching of hydraulic and pneumatic components and circuits should be delivered by practical work using hydraulic and pneumatic rigs. Candidates should prepare basic circuits to discuss and demonstrate the characteristics of hydraulic/pneumatic components and their interconnection.

## Plant hydraulics

This section of the unit covers hydraulic theory and hydraulic components and circuits.

## Practical competences

The candidates must be able to do the following:

- 40.1 Select an appropriate industrial hydraulic system and identify its function.
- 40.2 Identify hydraulic system components using standard terminology.
- 40.3 Prepare circuit diagrams using manual or computer aided draughting system.
- 40.4 Explain the operation of the hydraulic circuit and the major components.  
**Components:** pumps, actuators, directional control valves, flow control valves, pressure control valves
- 40.5 Use appropriate formulae and nomograms to obtain circuit parameters.  
**Parameters:** working pressure, maximum load capacity of actuators, actuator speed, flow rates, pipe size

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Hydraulic theory

- 40.6 Identify and use symbols recommended by CETOP (BS or ISO) for circuit diagrams.
- 40.7 Explain and use the formulae and nomograms to determine circuit parameters.  
**Parameters:** working pressure, maximum load capacity of actuators, actuator speed, flow rates, pipe size

### Hydraulic components and circuits

- 40.8 Draw a circuit diagram to show the layout of a basic hydraulic circuit and explain the function of each element.  
**Element:** reservoir, pump, relief valve, control valves, actuator
- 40.9 Describe the construction and operation of commonly used pumps in a circuit and compare their performance characteristics.  
**Pumps:** vane and piston (including variable types), gear
- 40.10 Describe the construction and operation of actuators.  
**Actuators:** linear, rotary, semi-rotary
- 40.11 Identify the various types of seals used in hydraulic systems and explain the reasons for the choice of materials.
- 40.12 State and compare the characteristics of hydraulic motors.  
**Characteristics:** torque, power, speed
- 40.13 Describe the construction of a reservoir and explain the purpose of each fitting.  
**Fitting:** oil level indicator, breather, filling-cap, drain plug, baffle plate
- 40.14 Describe the construction, operation and application of accumulators.  
**Accumulators:** deadweight, spring loaded, gas charged
- 40.15 State the properties of a typical hydraulic fluid.  
**Properties:** viscosity, lubricity, toxicity
- 40.16 Describe the merits and limitations of a range of hydraulic fluids.  
**Hydraulic fluids:** mineral oil, emulsions, water, glycol mix, synthetics
- 40.17 Explain the necessity of filtration in hydraulic systems and the method of rating filters (b values).
- 40.18 Describe the types of filters used and state their location within a system.  
**Types:** surface, depth
- 40.19 Describe fluid conductors and associated joints and fittings.  
**Fluid conductors:** pipe, tube, flexible hose
- 40.20 Describe the construction, operation and application of directional control valves.  
**Valves:** poppet, spool  
**Application (centre types):** closed, open, floating, tandem, regenerative,
- 40.21 Describe methods of valve actuation.  
**Methods:** manual, mechanical, electrical, pneumatic, electro-hydraulic

- 40.22 Explain the construction, operation and application of pressure control valves  
**Valves:** relief, reducing, unloading, sequence, counter balance
- 40.23 Describe the construction, operating and application of flow control valves.  
**Flow control valves:** non-compensated, pressure compensated  
**Flow control (methods):** meter-in, meter-out, bleed-off
- 40.24 Describe the construction, operation and application of check valves and pilot operated check valves.
- 40.25 Design circuits based on standard components to meet given control requirements eg lifting equipment and machine tools, simple process plant control.

## Plant pneumatics

This section of the unit covers compressed air theory and pneumatic components and circuits.

## Practical competences

The candidate must be able to do the following:

- 40.26 Prepare circuit diagrams using manual or computer aided draughting systems.
- 40.27 Identify pneumatic system components using standard terminology.
- 40.28 Select an appropriate pneumatic system and identify its function.
- 40.29 Explain the operation of the pneumatic circuits and the major components.  
**Components:** compressors, actuators, directional control valves, flow control valves, pressure control valves
- 40.30 Use appropriate formulae and nomograms to obtain circuits parameters.  
**Parameters:** working pressure, maximum load capacity of actuators, actuator speed, flow rates, pipe size

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Compressed air theory

- 40.31 Explain and use the formulae and nomograms to determine circuit parameters.  
**Parameters:** working pressure, maximum load capacity of actuators, actuator speed, flow rates, pipe size

### Pneumatic components and circuits

- 40.32 Identify symbols recommended by CETOP (BS or ISO) for circuit diagrams.
- 40.33 Draw a circuit diagram to show the layout of a basic pneumatic circuit and explain the function of the elements.  
**Elements:** compressor, receiver, control valves, relief valves, actuator
- 40.34 Describe conductors and associated joints and fittings  
**Conductors:** pipes, tubes, flexible hose
- 40.35 Describe the construction and operation of air service units.
- 40.36 Describe the construction and operation of actuators.  
**Actuators:** linear, rotary, semi-rotary
- 40.37 Describe seals used in pneumatic components eg 'O' rings.
- 40.38 Explain the construction and operation of valves.  
**Valves:** poppet, plate slide, spool, flow control, quick exhaust, timer (delay)
- 40.39 Describe the air flow through typical directional control valves.  
**Types:** 3/2, 4/2, 5/2, and 5/3, non return and shuttle (OR), two pressure (AND)
- 40.40 Describe methods of valve actuation.  
**Methods:** manual, mechanical, electrical, pneumatic, electro-pneumatic
- 40.41 Describe the construction and operation of pneumatic proximity-sensing devices.  
**Sensing devices:** air barrier, reflex, back pressure and pneumatic proximity switch
- 40.42 Describe the construction and operation of a range of pneumatic components.  
**Components:** pressure amplifier, vacuum suction nozzle and a pneumatic-electrical converter
- 40.43 Describe methods of eliminating maintained (trapped) signals should they occur.  
**Methods:** one way trips, reservoir and orifice, impulse generator
- 40.44 Use circuit diagrams to describe the functions required for simple sequential control of cylinders.  
**Functions:** control from more than one point (AND, OR), indirect control, automatic return and cycling, speed control, pressure dependant return, time dependant return/auto-cycling and a combination of AND, OR, time, speed and safety control

- 40.45 Use circuit diagrams to describe the control of up to four cylinders, making use of letters, signs and travel-step diagrams to identify cylinders and movements.
- 40.46 Use circuit diagrams and explain the principle of cascade for two group type and three or more group systems.
- 40.47 Describe and compare the application of pneumatic cascade sequencing with program logic control (PLC) systems.
- 40.48 Design circuits based on standard components to meet given control requirements, eg lifting equipment, machine tools, simple process plant control.

# Assessment

## Test specification for written question paper Plant Hydraulics and Pneumatics (2565-03-040)

This is a written examination paper lasting three hours with 10 questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Hydraulic theory	50
Hydraulic components and circuits	
Compressed air theory	50
Pneumatic components and circuits	

# 041 Plant Hydraulics and Pneumatics Practical Assignments

## Practical assignment 041/1: Investigating an Hydraulic System

### 1 Competence reference

40.1 – 40.5

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Writing materials, drawing board and Tee square or draughting machine or a computer system running appropriate software (eg word processing, computer aided draughting software) and a printer connected to the system, with paper loaded and set up ready to print.

Manuals for software.

Formulae sheet, nomograms, table of appropriate symbols related to the course and copy of section 3.

#### 2.3 Instructor notes

In this assignment candidates are required to investigate a real-life industrial hydraulic system and produce a report on it. Candidates must select and agree an appropriate system with their instructor and must be given the opportunity to inspect the system and obtain relevant information.

It is recommended that instructors visit an appropriate location with candidates and advise on selection of an hydraulic system. Instructors must provide candidates with formulae sheets/nomograms and table of symbols.

It is recommended that candidates use computer systems to produce the report for this assignment. The time allowed for this assignment is 15 hours.

### 3 Candidates' instructions

- 3.1 The time allowed for this assignment is 15 hours. You are required to produce a report on an industrial hydraulic system. You must select and agree a system with the instructor and visit the industrial site to obtain the relevant information.  
  
You are advised to read all the instructions before commencing work. If you do not understand all the instructions then please ask the instructor.
- 3.2 Visit an industrial location and select an hydraulic system, and agree it with the instructor.
- 3.3 Collect relevant information on chosen hydraulic system.
- 3.4 State the function of the system.
- 3.5 Prepare circuit diagrams and identify all components using standard terminology and symbols.
- 3.6 Explain the circuit operation in detail.
- 3.7 Explain the operation and describe the construction of all the major components:
  - 3.7.1 pumps
  - 3.7.2 actuators
  - 3.7.3 directional control valves
  - 3.7.4 flow control valves
  - 3.7.5 pressure control valves.
- 3.8 Use formulae/nomograms to obtain:
  - 3.8.1 working pressure
  - 3.8.2 maximum load capacity of actuators
  - 3.8.3 actuator speed
  - 3.8.4 flow rates
  - 3.8.5 pipe size.
- 3.9 Produce a report on computer, or manually, to include the above information.
- 3.10 Ensure your name is on all your work and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 15 hours. ( )
- 4.2 A hydraulic system selected and agreed with the instructor. [ ]
- 4.3 Relevant information on hydraulic system collected. [ ]
- 4.4 The function of the system stated. [ ]
- 4.5 Circuit diagrams prepared and all components identified using standard terminology. [ ]
- 4.6 The circuit operation explained in detail.
- 4.7 The operation explained and the construction of all the major components and symbols described:
  - 4.7.1 pumps [ ]
  - 4.7.2 actuators [ ]
  - 4.7.3 directional control valves [ ]
  - 4.7.4 flow control valves [ ]
  - 4.7.5 pressure control valves. [ ]
- 4.8 Parameters correctly obtained:
  - 4.8.1 working pressure [ ]
  - 4.8.2 maximum load capacity of actuators [ ]
  - 4.8.3 actuator speed [ ]
  - 4.8.4 flow rates [ ]
  - 4.8.5 pipe size. [ ]
- 4.9 Report completed. [ ]
- 4.10 Work handed in to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] .

Candidates who fail to achieve the requisite number of outcomes should be encouraged to carry out further research in order to complete the assignment satisfactorily.

# 041 Plant Hydraulics and Pneumatics Practical Assignments

## Practical assignment 041/2: Investigating a Pneumatic System

### 1 Competence reference

40.26 – 40.30

### 2 Preparation

#### 2.1 Location of test

The training centre or other venue where supervision and appropriate working conditions will be provided.

#### 2.2 Requirements

Writing materials, drawing board and Tee square or draughting machine or a computer system running appropriate software (eg word processing, computer aided draughting software) and a printer connected to the system, with paper loaded and set up ready to print.

Manuals for software

Formulae sheet, nomograms, a table of appropriate symbols related to the course and a copy of Section 3.

#### 2.3 Instructor notes

In this assignment candidates are required to investigate a pneumatic system and produce a report on it. Candidates must select and agree an appropriate system with their instructor and must be given the opportunity to inspect the system and obtain relevant information. It is recommended that instructors visit an appropriate location with candidates and advise on selection of a pneumatic system.

Instructors must provide candidates with formulae sheets/nomograms and table of symbols. The time allowed for this assignment is 15 hours.

It is recommended that candidates use computer systems to produce the report for this assignment.

### 3 Candidates' instructions

3.1 The time allowed for this assignment is 15 hours. You are required to investigate and produce a report on a pneumatic system. You must select and agree a system with your instructor and obtain relevant information about the system.

You are advised to read all the instructions before commencing work. If you do not understand all the instructions then please ask the instructor.

3.2 Select a pneumatic system and agree the system with the instructor.

3.3 Collect relevant information on the chosen system.

3.4 State the function of the system.

3.5 Prepare circuit diagrams and identify all components using standard terminology and symbols.

3.6 Explain the circuit operation in detail.

3.7 Explain the operation and describe the construction of all the major components:

3.7.1 pumps

3.7.2 actuators

3.7.3 directional control valves

3.7.4 flow control valves

3.7.5 pressure control valves.

3.8 Use formulae sheets/nomograms to obtain:

3.8.1 working pressure

3.8.2 maximum load capacity of actuators

3.8.3 actuator speed

3.8.4 flow rates

3.8.5 pipe size.

3.9 Produce a report to include the above information (either manually or using a computer).

3.10 Ensure your name is on all your work and hand it in to the instructor.

## 4 Marking

- 4.1 Assignment completed in 15 hours. ( )
- 4.2 A pneumatic system selected and agreed with the instructor. [ ]
- 4.3 Relevant information collected. [ ]
- 4.4 The function of the system stated. [ ]
- 4.5 Circuit diagrams prepared and all components identified using standard terminology.
- 4.6 The circuit operation explained in detail. [ ]
- 4.7 The operation explained and the construction of all the major components and symbols described:
  - 4.7.1 pumps [ ]
  - 4.7.2 actuators [ ]
  - 4.7.3 directional control valves [ ]
  - 4.7.4 flow control valves [ ]
  - 4.7.5 pressure control valves [ ]
- 4.8 Parameters correctly obtained:
  - 4.8.1 working pressure [ ]
  - 4.8.2 maximum load capacity of actuators [ ]
  - 4.8.3 actuator speed [ ]
  - 4.8.4 flow rates [ ]
  - 4.8.5 pipe size [ ]
- 4.9 Report produced. [ ]
- 4.10 Work handed to the instructor. [ ]

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all items marked with a [ ].

Candidates who fail to achieve the requisite number of outcomes should be encouraged to carry out further research in order to complete the assignment satisfactorily.

## Introduction

This unit builds on the electrical principles previously studied in the diploma level. It aims to cover a variety of fundamental aspects of circuit and network theory. In addition, a section on reliability is included. Much of the work in this unit requires a compatible level of supporting mathematics to assist the candidates to put into practice the various theoretical concepts. It is not intended that the mathematics is separately examined.

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Circuits and networks

- 42.1 Calculate steady state current and voltage conditions in ac circuits using symbolic notation (j-operator).  
**Ac circuits:** resistors, capacitors and inductors in series and parallel circuits
- 42.2 Calculate the currents and voltages in ac circuits using mesh and nodal analysis.  
**Networks:** two loops containing R, L and R, C
- 42.3 Calculate currents, voltages and power in single-phase and balanced three-phase circuits  
**Circuits:** resistance and reactance connected in series and in parallel
- 42.4 Calculate rms voltages and currents of waveforms containing harmonics.
- 42.5 Determine the effects of harmonics on power factor and power.
- 42.6 Calculate voltage, current, power and power factor in circuits connected across an ac supply containing harmonics.  
**Circuits:** series and parallel containing resistance and either inductance or capacitance  
**Harmonics:** fundamental, 2nd, 3rd
- 42.7 Explain harmonic resonance and show in circuits containing R, L and C, at the nth harmonic,  $n\omega L = 1/n\omega C$
- 42.8 Define the performance of a four terminal, two port network in terms of Y parameters ( $Y_{11}$ ,  $Y_{12}$ ,  $Y_{21}$  and  $Y_{22}$ ) and Z parameters ( $Z_{11}$ ,  $Z_{12}$ ,  $Z_{21}$  and  $Z_{22}$ ).
- 42.9 Derive general expressions for the performance of two port, four terminal, active and passive networks in terms of their Y and Z parameters.  
**Performance:** input impedance, output impedance, forward voltage and forward current ratios
- 42.10 Determine the performance, given values of external components and the appropriate Y or Z parameters, of simple four terminal networks.  
**Performance:** input impedance, forward voltage, forward current ratios
- 42.11 Define the surge/characteristic impedance of a line/network.
- 42.12 Explain terms associated with the representation of transmission of lines.  
**Terms:** infinite, finite, loss free
- 42.13 Explain types of wave associated with transmission lines.  
**Wave:** incident, reflected, standing
- 42.14 Explain how reflected and standing waves are generated under mismatched conditions.
- 42.15 Define attenuation in dBs and explain the operation of resistive attenuators.
- 42.16 Solve problems associated with attenuators.  
**Problems:** calculation of surge impedance, attenuation, component values  
**Attenuators:** single section symmetrical T and  $\pi$
- 42.17 Solve problems involving series and parallel tuned-circuits.  
**Problems:** calculation of dynamic resistance, inductance, capacitance, Q factor, resonant (centre), frequency, bandwidth
- 42.18 Solve problems where a tuned-circuit is mutually coupled to a resistive load.  
**Problems:** calculation of dynamic resistance, inductance, capacitance, Q factor, resonant (centre), frequency, bandwidth
- 42.19 Derive an expression for the input impedance of a tuned-circuit coupled by mutual inductance to a secondary tuned-circuit.
- 42.20 Sketch graphs to illustrate the changes in the response curve of secondary current/frequency as the value of the coupling coefficient  $k_c$  is increased.
- 42.21 Define critical coupling and state that the value of coupling coefficient for critical coupling is  $k_c = 1/\sqrt{Q_p Q_s}$
- 42.22 State that the 3dB bandwidth of critically-coupled identical tuned-circuits is  $B = \sqrt{2} \frac{f_r}{Q}$
- 42.23 Perform calculations on tuned critically coupled-circuits.  
**Calculations:** undamped and damped Q factor, mutual inductance, self inductance, capacitance, coupling coefficient

42.24 Analyse dc and ac circuits using circuit theorems.

**Theorems:** Thevenin, Norton

**Circuits:** restricted to two loops only

42.25 Use Star-Delta and Delta-Star transformations to simplify circuits consisting of resistance and reactance.

**Circuits:** T (Star),  $\pi$  (Delta)

42.26 Perform calculations involving the conversion of Thevenin to Norton and Norton to Thevenin equivalent circuits.

### Filters

42.27 Sketch the ideal frequency response characteristics of a range of filters.

**Filters:** low pass, high pass, band pass, band stop

42.28 Sketch circuits of single-pole RC filters.

**Filters:** low pass, high pass

42.29 Sketch frequency response characteristics of filter network and indicate the 3dB frequency.

**Filters:** low pass, high pass

42.30 Determine the ultimate rate of signal voltage attenuation for a single-pole RC filter circuit (6dB/octave 20dB/decade)

42.31 Sketch waveforms to show the effect of passing a complex waveform through low-pass and high-pass filter circuits.

42.32 Perform calculations to establish an expression for the resulting waveform when passing a complex waveform through filter networks.

**Complex waveforms:** limited to a fundamental plus 1 harmonic

**Filter Networks:** low pass, high pass

42.33 Sketch LCR band-pass and band-stop filter circuits and their frequency response curves.

42.34 Describe the use of operational amplifiers to replace inductors in active filters, and state the benefits.

42.35 Sketch circuits of operational amplifier active filters.

**Filters:** high pass, low pass

42.36 Derive transfer functions in terms of  $j\omega$  for operational amplifier active filters.

**Filters:** high pass, low pass

42.37 Perform calculations on active filters.

**Calculations:** mid band gain, high and low -3dB frequency, component values

### Transients and transformers

42.38 Explain that electrical transients are generated by circuits containing components that store and dissipate energy.

**Components:** capacitors, inductors (energy storage), resistors, circuit losses (energy dissipation)

42.39 Explain that CR and LR series circuits experience current and voltage exponential growth or decay when subjected to a step input.

42.40 Sketch graphs of variation of current and voltage in CR and LR series circuits subjected to a step change and calculate time constant.

42.41 Calculate instantaneous voltage and current values in CR and LR series circuits.

42.42 Show using the formulae  $\frac{N_p^2}{N_s} = \frac{R_p}{R_s}$  that the transformer

can be used for impedance matching where  $Z_p$  = primary load,  $Z_s$  = secondary load,  $N_p$  = primary turns,  $N_s$  = secondary turns.

42.43 Perform calculations on transformer matching using the formulae in 42.42.

42.44 Define transformer regulation as the change in secondary voltage between no-load and full-load, usually expressed as a percentage of secondary emf.

42.45 Describe with the aid of diagrams the construction and application of a range of transformers.

**Transformers:** auto, current, power, audio frequency, radio frequency

### Reliability

42.46 Explain the importance of high reliability in typical electrical and electronic applications.

42.47 Define reliability (R) in terms of probability of success for a specified time.

42.48 Define mean time between failures (m).

42.49 Define failure rate ( $\lambda$ ) and explain the unit percent per 1000 hours.

42.50 Draw and explain a graph of failure rate/time for a system (the bath tub diagram).

42.51 State the relationship between reliability, failure rate and time.  $R = \exp(-\lambda t)$ .

42.52 Draw the graph of reliability/time (the survival characteristic).

42.53 Use the law of compound probability to show that the failure rate of a system is the sum of the failure rates of all its component parts.

42.54 Calculate the reliability of a system from the component failure rates, using given data.

42.55 Calculate the reliability of two identical units employed in a main/standby situation.

- 42.56 Describe the effect on failure rate of operating components well below their power rating.
- 42.57 Describe how reliability may be improved by controlling the environment in which the system operates.
- 42.58 Describe why the reliability of hardware, firmware and software is important to ensure the overall reliability of a computer controlled system.
- 42.59 Explain the importance of accurate reporting and recording of failures.

### Associated mathematics

The following section is intended to illustrate the topic areas and the applications of mathematics that the candidates require in order to complete the applications work arising from this unit.

#### Trigonometric functions

- 42.60 Represent sine, cosine and harmonic waveforms using  $y = A \sin(\omega t + \phi)$  and  $y = A \cos(\omega t + \phi)$ .
- 42.61 Use mathematical notation to represent travelling waves on open circuit and short circuit transmission lines.
- 42.62 Solve equations involving inverse trigonometric functions.  
**Equations:** eg the results of angles being greater than 90, 180, 270, 360 degrees, instantaneous values of waveforms in 42.60, power factor correction

#### Calculus

- 42.63 Differentiate, applying standard rules, a range of functions.  
**Functions:** a constant,  $x^n$ ,  $A \cos(x)$ ,  $B \sin(x)$ ,  $e^x$
- 42.64 Solve circuit problems involving rates of change.  
**Rates of change:** eg  $i = dq/dt$ ,  $v = L di/dt$ ,  $V = C dv/dt$
- 42.65 Integrate applying standard rules a range of functions.  
**Functions:** eg 1,  $x^n$ ,  $A \cos(x)$ ,  $B \sin(x)$  etc,  $1/(1-x^2)^{-1/2}$ ,  $e^x$
- 42.66 Calculate the area under a graph representing a given function between two points using definite integrals.
- 42.67 Determine mean and rms values of sine and cosine functions using integration between the limits  $0 \rightarrow \pi/2$
- 42.68 Solve problems involving calculations of mean and rms values of practical waveforms arising from power switching using diodes, thyristors and triacs in phase control and burst firing circuits where the time periods are less than half a cycle.

#### Exponential functions and complex numbers

- 42.69 Reduce exponential functions using natural logs ( $\ln$ ) and inverse logs ( $\ln^{-1}$ ) into linear form to solve electrical problems.  
**Electrical problems:** currents, voltages, time, reliability, meantime between failures
- 42.70 Represent ac quantities using operator  $\omega 4$ .
- 42.71 Represent a complex equation on an Argand diagram.
- 42.72 Perform addition, subtraction, multiplication and division of complex numbers.
- 42.73 Use polar form ( $r \angle \theta$ ) in calculations involving division and multiplication of complex numbers.
- 42.74 Convert polar form of complex numbers to Cartesian form and Cartesian to polar.
- Matrices and determinants**
- 42.75 Use matrices to represent performance of 2 port, 4 terminal networks in terms of A, G, H, Y and Z parameters.
- 42.76 Solve simultaneous equations using determinants.
- 42.77 Convert from one parameter set to another, eg from Z to Y, G to H.
- 42.78 Add, subtract and multiply 2 x 2 matrices.

#### Graphical representations

- 42.79 Use log/linear graph paper to present frequency response of electrical/electronic circuits in graphical form and interpret practical results.
- 42.80 Calculate voltage, current and power ratios in dB and represent the results in graphical form by plotting the results against log frequency.
- 42.81 Calculate phase shift at various frequencies and plot phase (log frequency) along with the results in 42.80 to form a Bode diagram.

# Assessment

## Test specification for written paper Advanced Electrical Principles (2565-03-042)

This is a written examination paper lasting two hours with six questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Circuits and networks	50
Filters	15
Transients and transformers	15
Reliability	20

## Introduction

The aim of the unit is to provide a general background in control theory with details of the construction and performance of the associated practical equipment over a range of applications, using an inter-disciplinary approach. Much of the work in this unit requires a compatible level of supporting mathematics to assist the candidates to put into practice the various theoretical concepts. It is not intended that the mathematics is separately examined.

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Control principles

- 43.1 Explain a range of terms relating to control systems.  
**Terms:** open and closed loop control, negative and positive feedback, input signal (reference or set value), output signal (reset value), error signal, signal conditioning, open and closed loop transfer functions, comparators, offset, control variable
- 43.2 Define a closed loop proportional control system as one where the feedback is proportional to the difference between the input and output signals (error).
- 43.3 Explain why the closed loop formed by the feedback always acts to reduce the amplitude of the error (negative feedback), for the operation of the system to remain stable.
- 43.4 Describe, with the aid of block diagrams, examples of simple closed loop control systems with proportional feedback.  
**Examples:** control of position, shaft speed, temperature, voltage, pressure
- 43.5 Explain that in control systems, sensors are required to sense the level of the input and/or the output to provide signals proportional to the quantities being measured and also, an actuator may be required at the output to convert the output signal to a suitable form to drive the load.  
**Systems:** control of position, shaft speed, temperature, voltage, pressure
- 43.6 Explain that closed loop systems are error actuated and hence the error is never reduced completely to zero.  
**Systems:** control of position, shaft speed, temperature, voltage, pressure

### Sensors (transducers)

- 43.7 Describe, with the aid of diagrams, the construction, the principles of operation, and characteristics of a range of sensors.  
**Sensors:** diaphragm and bellows types including capacity, inductive and piezoelectric transducers for pressure measurement; load cells and strain gauges, including bridges techniques for measurement of weight; thermistors, thermocouples and resistance thermometers for temperature measurement; linear variable differential transformer and resistance potential divider for linear displacement; digital optical encoders for rotational displacement; tachogenerators and pulse counting techniques with magnetic induction for measurement of angular velocity; venturi with pressure transducers, turbine meters and doppler frequency shift meters for measurement of liquid flow
- 43.8 Select appropriate sensors/transducers for common applications using manufacturers' or suppliers' data sheets to establish practical specifications and describe the requirements for signal conditioning where appropriate.
- 43.9 Perform calculations relating to the performance of sensors/transducers, using graphical characteristics and established formulae.  
**Calculations:** eg bridge calculations with resistors and strain gauges, voltage calculations with thermocouples and thermistors, (working in absolute temperature) Bernoulli's equations for flow measurement

### Amplifiers and actuators

- 43.10 Explain why some form of power amplification is required in most practical forms of closed loop proportional control system.
- 43.11 Explain that in some types of control systems it is often more convenient for the actuator to be an integral part of the amplifier.  
**Types of system:** hydraulic, pneumatic
- 43.12 Describe, with the aid of diagrams, the construction and principle of operation of various types of amplifier.  
**Types:** electronic (differential-input operational and power types), hydraulic, pneumatic
- 43.13 Explain how an electronic differential amplifier may function as an error detector in a closed loop system.
- 43.14 Compare the characteristics of the types of amplifier in 43.12, using manufacturers' or suppliers' data.  
**Characteristics:** forward transfer ratios, power output, operating frequency (bandwidth)
- 43.15 Explain the reasons why electronic amplifiers may be used with other types of power amplifier, eg hydraulic and pneumatic, to form a hybrid system.  
**Reasons:** electronic amplifiers provide high gain at low cost, but have low output power

43.16 Describe briefly the characteristics of a range of electric motors used in industrial control systems.

**Motors:** dc motors (including brushless permanent magnet types), ac motors, stepper motors

### Feedback and performance criteria

43.18 Define the following terms relating to factors influencing the performance criteria of control systems.

**Terms:** coulomb friction, stiction, viscous friction, linear and angular systems inertia.

43.19 Describe the effect of a gearbox on the effective inertia and viscous friction.

43.20 Describe the effect of gear backlash in a control system.

43.21 Derive differential equations for speed and position control systems where the motor torque is proportional to the error signal.

**Equations:** linear, first and second order

43.22 Sketch a graph showing the response of the system in 43.21 to a step input.

43.23 Identify from the graph in 43.22, the defining features of the system response.

**Features:** overshoot, period of damped oscillation, time constant, settling time

43.24 Calculate, from the equations derived in 43.21, the undamped natural frequency and damping ratio.

43.25 Define 'system type number' and explain how it can be used to calculate the damping ratio of a system from test results.

43.26 Calculate the steady state error in simple closed loop control systems from given practical data.

**Systems:** speed control, position control

### Frequency response and system testing

43.27 Explain that although practical input signals applied to control systems during normal operation are not normally pure sinewaves, it is a very useful signal for test purposes since it contains one fundamental frequency only.

43.28 Explain that a sinusoidal signal can be represented in mathematical form as  $v = V(\cos\theta + j\sin\theta)$  or  $v = V(\sin\omega t + \phi)$ , where  $V$  is the amplitude,  $v$  is the angular frequency in radians,  $t$  is the time in seconds and  $\phi$  is the phase angle.

43.29 State that the transfer function of a first order system can be written in terms of operator  $j\omega$  as  $G(j\omega) = 1/(1+j\omega T)$  where  $T$  is the time constant of the system in seconds.

43.30 State that the magnitude of  $G(j\omega) = 1/(1+\omega^2 T^2)^{1/2}$  and  $\tan\phi = -\omega T$  is a convenient means of relating the sinewave response of the system to parameters of the practical system, ie the forward ratio and time constant of the practical system.

43.31 State that the transfer function of a second order system can be written in terms of operator  $j\omega$  as

$G(j\omega) = [1 - (\omega/\omega_n)^2 - j2\zeta(\omega/\omega_n)]$  where  $\omega_n$  is the natural angular frequency and is the damping ratio.

43.32 State that for a second order system, the magnitude of  $G(j\omega)$  is given by:  
 $1/\{[1 - (\omega/\omega_n)^2]^2 + [2\zeta(\omega/\omega_n)]^2\}^{1/2}$ , and for the phase angle,  
 $\tan\phi = [2\zeta(\omega/\omega_n)] / [1 - (\omega/\omega_n)^2]$

43.33 Perform calculations to determine the forward transfer ratios and phase angles of first and second order systems at given sinewave input frequencies using typical practical data for the system parameters.

43.34 Plot graphs of the results of magnitude in dB and phase angle against log frequency from the calculations in 43.33.

43.35 Explain that the graphs plotted in 43.34 are known as Bode diagrams and show that they can be constructed from a series of straight line approximation.

43.36 Construct Bode diagrams (plots) using typical data for practical first and second order systems.

43.37 Describe test methods for obtaining practical results of open and closed loop frequency response of a control system.

43.38 Describe the use of standard test equipment for the test method described in 43.37.

**Equipment:** low frequency oscillator, variable phase oscillator, phase metre, transfer function analyser

### System stability

43.39 Explain that for a closed loop system to be stable, the open loop gain of the system must be less than unity when the phase angle is  $-180^\circ$  and this leads to the use of gain and phase margins to determine the degree of stability of a practical system.

43.40 Define 'gain' and 'phase' margins as the magnitude of the gain and phase respectively at the frequency where the gain magnitude reaches unity (the gain cross over).

43.41 Determine the values of gain and phase margins from Bode plots obtained from practical stable systems.

### Nyquist diagrams

- 43.42 Explain that mathematical expressions such as  $G(j\omega) = 1/(1 + j\omega T)$  where  $T$  is the time constant of the system in seconds can also be represented in the form of a single polar plot, (magnitude in dB for each phase angle), known as a Nyquist diagram.
- 43.43 Show by means of a Nyquist diagram that the path of the locus, indicating the magnitude and phase angle of an open loop response, as frequency increases, can be used to indicate the closed loop system stability, ie gain and phase margins.
- 43.44 Draw Nyquist plots of the open loop frequency response of control systems from typical data and determine if the system is stable and the respective magnitudes of the gain and phase margins.

### Use of controllers and compensation techniques

- 43.45 Explain that the stability of a control system can be improved by changing its frequency response to increase the gain and phase margins.
- 43.46 Describe, with the aid of diagrams, methods of changing the frequency response of a control system by introducing velocity feedback, transient velocity feedback and lead or lag compensating networks.
- 43.47 Identify, with the aid of circuit diagrams, resistance-capacitance networks to provide compensation as in 43.46.
- 43.48 Show, using Bode and Nyquist diagrams, the effects of frequency compensation on the open loop response of control systems.

### Process control

- 43.49 Explain the terms associated with process control plant.  
**Terms:** set point, deviation, offset, proportional band, transport delay
- 43.50 Explain that control systems operate in either one or two modes.  
**Modes:** continuous (where the control has uninterrupted inputs and outputs), discrete (where the control process involves a number of discrete, or timed events)
- 43.51 Explain how the performance of a process control can be improved by the use of controllers operating in a variety of modes.  
**Modes:** two-step, an error activated switch, proportional mode (P) where the control action is proportional to the error, derivative mode (D) where the controlling action is proportional to the rate at which the error is changing, integral mode (I) where the control action continues as long as the error persists

- 43.52 Sketch graphs to show the response of a system to a step input for various control actions.

**Control actions:** proportional plus derivative, proportional plus integral, three term control, (a combination of P, I and D)

### Digital systems

- 43.53 Explain how open and closed loop control systems can incorporate signal sampling rather than continuous control, thus providing a means of controlling a process by means of digital computers with suitable interfacing, eg digital to analogue and analogue to digital converters.
- 43.54 Describe with the aid of block diagrams, the operation of computer controlled systems.  
**Systems:** control of position and speed, security and alarm, air conditioning, vehicle engine management.
- 43.55 Describe, for each of the systems in 43.54, the types of sensors and actuators required.
- 43.56 Explain that signal conditioning and correction in a digitally controlled system can be implemented using either hardware or software methods, and that software methods are likely to provide greater flexibility.

### Programmable logic controllers (PLC)

- 43.57 Identify using manufacturers' data the operational characteristics of typical industrial programmable logic controllers and their power requirement.  
**Programmable logic controllers:** modular, rack-mounted, stand-alone  
**Operational characteristics:** memory size, speed of operation, number and type of input/outputs
- 43.58 State the various types of transducer (sensors) and actuators commonly used with industrial PLC systems.  
**Transducers (sensors):** mechanically operated switches, optical sensors, electro-magnetic sensors  
**Actuators:** motors, relays and contactors, solenoids
- 43.59 Sketch a simple PLC block diagram consisting of input port, image and main memory, central processing unit (CPU), output port and buses, and explain the overall operation.
- 43.60 Explain how a range of logic functions can be generated using relay switching.  
**Range:** AND, OR, XOR, NAND, NOR
- 43.61 Explain the process of scanning inputs via image memory, monitoring logic conditions and updating outputs.
- 43.62 Define the scan rate in terms of bytes/second and explain that scan rate is determined by clock frequency and size of memory.
- 43.63 Explain that phasing errors occur when an input port changes its state twice before the input image memory is updated.

43.64 Explain the need for interfacing circuits and describe the different types of I/O ports available for PLC interfacing.

**Input ports:** opto-isolated digital

**Output ports:** relay, transistor, analogue, communication

43.65 Describe the protocols used in signal communication.

**Protocols:** RS232, RS422, IEE488, 20mA

43.66 Describe the practical implementation of communication links.

**Links:** twisted pair, coaxial, fibre optic

43.67 Define the response time of a PLC as the delay between an input being turned on and an output changing state and explain the causes of delay.

**Causes:** mechanical response of output device, electrical response of input device, scan update of image memory

43.68 Explain with the aid of block diagrams the use of A/D and D/A converters in PLC systems.

43.69 State typical values of industry standard analogue voltage and current input/output signals, eg 5V for digital and analogue systems, 0-10V for analogue, 4-20 mA for current output.

43.70 Define the term 'resolution' as applied to D/A and A/D converters and describe the relationship between analogue inputs/outputs and word length eg 8 bit, 12 bit and 16 bit.

43.71 Express numbers using various number systems.

**Systems:** binary, hexadecimal, BCD

43.72 Describe how bipolar voltages can be converted to unipolar voltages using a summing amplifier (opamp).

### Applications and programming

43.73 Describe simple industrial applications of PLCs.

**Applications:** on/off switching, temperature control, motor speed control, conveyor belt sequencing operations

43.74 Describe with the aid of block diagrams the type of sensors (transducers) and actuators used in given applications.

**Applications:** on/off switching, temperature control, motor speed control, conveyor belt sequencing operations

43.75 Write programs using flow charts and recognised programming methods, eg ladder diagrams, to perform simple operations.

**Operations:** logic control, on/off delays, timing, sequencing, counting

### Associated mathematics

This section of the syllabus is intended as a guide to the mathematics that candidates are likely to find helpful in carrying out practical calculations arising from the topics in the main body of this unit.

#### Exponential functions

43.76 Solve equations involving exponential functions arising from electrical problems.

**Equations:**

$$i = I(1 - e^{-t/CR}), \quad V = E(1 - e^{-tR/L})$$

for electrical circuits.

#### Complex numbers

43.77 Represent ac quantities using operator  $jv$ .

43.78 Perform addition, subtraction, multiplication and division of complex numbers.

43.79 Use polar form in calculations involving  $jv$ .

43.80 Convert polar to cartesian form and cartesian to polar form.

43.81 Solve series and parallel ac linear circuit problems.

43.82 Solve problems involving amplitude and phase shift in simple RC networks.

#### Differential equations

43.83 Apply simple modelling techniques to represent the performance of mechanical and electrical systems based on differential equations.

**Systems:** electrical L, C and R series and parallel circuits, mechanical spring mass and damper systems, closed loop position and speed control systems

43.84 Determine transient and steady state solutions of first and second order differential equations arising from 43.83.

#### Laplace transforms

43.85 Explain the general use of Laplace transforms and their application to the solution of electrical and electronic circuit problems.

43.86 Explain that in the s-domain, a transfer function of a network is given by:

$$T(s) = (\text{Laplace transform of output}) / (\text{Laplace transform of input})$$

43.87 Describe the use of Laplace transform tables to obtain the Laplace transforms of unit amplitude signals which are functions of time.

**Signals:** impulse, step, ramp, exponential growth and decay, sinewave, cosinewave.

- 43.88 State the basic rules involved in working with Laplace transforms.  
**Rules:** if a function is multiplied by a constant, the Laplace transform is multiplied by the same constant; if an equation includes a sum of separate quantities, the Laplace transform of the equation is the sum of the separate Laplace transforms; assuming zero initial conditions, the Laplace transform of a first derivative of a function  $f(t)$  is  $sF(s)$ ; assuming zero initial conditions, the Laplace transform of a second derivative of a function  $f(t)$  is  $s^2F(s)$ ; the Laplace transform of an integral of a function  $f(t)$  is  $1/s [F(s)]$
- 43.89 Explain that when algebraic manipulations have taken place in the  $s$ -domain, the outcome can be transformed back to the time domain using Laplace transform tables in the inverse manner.
- 43.90 Use operator ' $s$ ' in place of  $j\omega$  to provide simple transfer functions and Laplace transforms to obtain steady state and transient solutions to simple linear circuit and system problems for a range of small-signal input functions.  
**Input functions:** step, ramp, exponential, sine wave
- 43.91 Use Laplace transforms to solve network problems arising from electrical system models in 43.83.

### Graphical representation

- 43.92 Calculate voltage, current and power ratios in dB and represent the results in graphical form by plotting the results against frequency.
- 43.93 Calculate phase shift at various frequencies and plot phase/log frequency along with the results in 43.92 to form a Bode diagram.
- 43.94 Use the results from 43.92 to show that a polar plot (Nyquist diagram) can be used as an alternative form of plotting both gain and phase shift on a single diagram.
- 43.95 Use Bode and Nyquist diagrams of open loop response of closed loop control systems to solve problems relating to closed loop stability.

# Assessment

## Test specification for written paper Control Systems and Applications (2565-03-043)

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** questions.

The examination paper will cover the knowledge specifications:

<b>Topic</b>	<b>Approximate % examination weighting</b>
Control principles	10
Sensors (transducers)	10
Amplifiers and actuators	10
Feedback and performance criteria	} 40
Frequency response and system testing	
System stability	
Nyquist diagrams	
Use of controllers and compensation techniques	} 30
Process control	
Digital systems	
Programmable logic controllers (PLC)	
Applications and programming	

## Introduction

Much of the study of the technical units at the diploma and advanced diploma levels has integrated the mathematical content in with the applied technology. This unit, at the higher diploma level, provides additional mathematics to both advance and broaden a candidate's understanding of mathematics to supplement other studies at this level and to also provide a sound foundation for further study. Where possible, it is expected that worked examples will be selected to represent relevant engineering problems.

## Knowledge requirements

Instructors must ensure that candidates are able to:

### Trigonometry

- 47.1 Prove simple trigonometrical identities involving  $\sin A$ ,  $\cos A$ ,  $\tan A$ ,  $\operatorname{cosec} A$ ,  $\sec A$  and  $\cot A$ .
- 47.2 Use trigonometrical identities to assist in the solution of simple trigonometrical equations.
- 47.3 Manipulate and use the compound angle formulae expansions of  $\sin(A+B)$ ,  $\cos(A+B)$ ,  $\tan(A+B)$  in the solution of trigonometric problems.
- 47.4 Manipulate and use the double angle formulae expansions of  $\sin 2A$ ,  $\cos 2A$  and  $\tan 2A$  in the solution of trigonometric problems.
- 47.5 Manipulate and use the half angle formulae expansions of  $\sin A$ ,  $\cos A$  and  $\tan A$ , including those using the substitution  $t = \tan \frac{A}{2}$  in the solution of trigonometric problems.
- 47.6 Transform expressions of the form  $a \sin \theta \pm b \cos \theta$  to the form  $r \sin(\theta + \alpha)$  and use this to solve problems.

### Geometry

- 47.7 Create a diagram from given data to a suitable scale.
- 47.8 Estimate the area under curves between given limits by using the mid-ordinate, trapezoidal and Simpson rules.
- 47.9 State Pappus' theorems.
- 47.10 Use Pappus' theorems to calculate volumes and surface areas of curved shapes.

### Algebra

- 47.11 Sketch graphs of the type  $y - ae^{bx}$  and  $a(1 - e^{bx})$  for given values of  $a$  and  $b$

- 47.12 Determine exponential / logarithmic laws by plotting graphs on log-log or log-linear graph paper for functions such as  $y - ax^n$ ,  $y - ae^{bx}$

- 47.13 Determine the partial fractions for expression in which the denominator contains linear factors, repeated linear factors or quadratic factors ie functions of the following types

$$\frac{f(x)}{(x-a)(x-b)}, \quad \frac{f(x)}{(x-a)^3}, \quad \frac{f(x)}{ax^2+bx+c}$$

### Complex Numbers

- 47.14 Define a complex quantity as a number which has real and imaginary parts.
- 47.15 Use the definition  $j = \sqrt{-1}$  to identify the imaginary parts of a complex number.
- 47.16 Describe vectors and phasors as complex quantities.
- 47.17 Represent complex quantities on an Argand diagram using cartesian ( $a \pm jb$ ) and polar ( $r \angle \theta$ ) forms.
- 47.18 Identify  $\pm j$  and  $\pm \sqrt{j}$  as instructions to rotate phasors through angles of  $\pm 90^\circ$  and  $\pm 45^\circ$  respectively.
- 47.19 Convert complex quantities from cartesian form to polar form and vice versa.
- 47.20 Perform scalar multiplication and division on complex numbers in cartesian form.
- 47.21 Define and use the conjugate of a complex number.
- 47.22 Calculate the sums and differences of complex quantities.
- 47.23 Calculate the products and quotients of complex quantities.
- 47.24 Solve quadratic equations which produce complex roots.

### Matrices and determinants

- 47.25 Calculate the sum and differences of TWO matrices (2x2 only).
- 47.26 Calculate the product of TWO 2x2 matrices.
- 47.27 Solve a pair of linear simultaneous equations using matrices.
- 47.28 Evaluate a 2x2 determinant.
- 47.29 Solve a pair of linear simultaneous equations using determinants.

## Differential Calculus

47.30 Derive, from first principles, the differential coefficients for function such as  $y = ax^n + b$

47.31 Use the notations  $dy/dx$ , and  $d^2y/dx^2$  or  $f'(x)$  and  $f''(x)$  for derived expressions noting that other variables, such as V, A, h and r, may be used for Volume, Area, height and radius.

47.32 Differentiate, by rule, a range of functions and combinations of functions noting that the constants may be positive, negative or fractional numbers.

### Range of functions:

i  $y = ax^n \pm b^x m a \sqrt{x^b}$  -where a, b, m, and n are constants

ii  $y = a \sin (b\theta + a)$  -similarly for other trigonometric functions

iii  $y = a \ln (bx)$  -similarly for functions involving  $\log_{10}x$  and  $e^x$

iv  $y = ab^x$

47.33 Differentiate, by rule, functions of functions, products and quotients of functions for the range given in 47.32.

47.34 Obtain the first and second derivatives for the range of functions given in 47.32.

47.35 Determine turning points for the range of functions given in 47.32 and identify these as local maxima, local minima or points of inflection.

47.36 Solve problems involving maximum and minimum values.

47.37 Identify and use the first and second derivatives of a displacement / time function as velocity and acceleration respectively, for linear and angular motions.

## Integral calculus

47.38 Determine the indefinite integrals of functions for the range given in 47.32 including integrals of the form  $f'(x) / f(x)$ ,  $f'(x) [f(x)]^n$ , integration by substitution and integration by parts.

47.39 Evaluate definite integrals of functions for the range given in 47.32 between various limits.

47.40 Solve problems involving definite integration by partial fractions of functions of the type given in 47.32.

47.41 Evaluate the area under a curve from the range in 47.32 as the integral between given limits.

47.42 Express and evaluate, by integration, the area between two curves from the range in 47.32.

47.43 Define and calculate the mean and root mean square values of the functions in 47.32 ii).

47.44 Calculate the centroid, first and second moments of area of plane figures.

## Differential equations and Laplace transforms

47.45 Solve, by direct integration, equations of the form

$$\frac{dy}{dx} + bx + c = 0$$

47.46 Solve, by assuming a solution of the form  $\theta = Ae^{bt}$ , an

$$\text{equation of the form } \frac{d\theta}{dt} = k\theta$$

47.47 Solve differential equations arising from practical situations.

47.48 Define Laplace transformation and inverse transformation.

47.49 Use Laplace transforms and inverse transforms to solve first and second order differential equations for functions of t when  $f(t) = k, t^n, e^{kt}, \sin \omega t, \cos \omega t, \sinh \omega t, \cosh \omega t$ , and combinations of these.

## Progressions and series

47.50 Define arithmetic progressions (AP's) and geometric progressions (GP's) as progressions having a common difference and common ratio between successive terms respectively.

47.51 Evaluate the sum of n terms of an arithmetic progression using the formula

$$S_n = \frac{n[2a + d(n-1)]}{2}, \text{ where } a \text{ is the first term, } d \text{ is the}$$

common difference and n is the number of terms.

47.52 Evaluate the sum of n terms in a geometric progression using the formula

$$S_n = \frac{a(1-r^n)}{(1-r)}, \text{ where } a \text{ is the first term, } r \text{ is the common}$$

ratio and n is the number of terms.

47.53 Deduce general expressions for the  $n^{\text{th}}$  term of simple arithmetic and geometric progressions.

47.54 Expand the general binomial expression  $(a+b)^n$  for any positive integer value of n.

47.55 Write a single specified term from the expansion given in 47.54.

47.56 Use the binomial series to expand expressions such as  $(1+x)^n$  for  $-1 < x < 1$

47.57 Use the binomial series to estimate the effects on the subject of a formula, involving power laws, when there are small percentage errors in the variables.

- 47.58 Describe the concept of convergence of a series to a limit.
- 47.59 Define the radius of convergence of a power series.
- 47.60 Use the ratio test to determine the radius of convergence of series expansions for functions such as  $e^x$ ,  $\sin x$ ,  $\log_e (1+x)$  and  $(1+x)^n$

### **Complex waveforms**

- 47.61 State that any periodic waveform can be regarded as the sum of the fundamental and harmonically related sinusoidal components.
- 47.62 Define the terms fundamental, second and third harmonic.
- 47.63 Show graphically the effects of adding second and third harmonics to a fundamental waveform.
- 47.64 Show graphically the effect of changing the amplitude and phase of the second harmonic component.
- 47.65 Derive an expression for a waveform comprising the fundamental and harmonic components of specified amplitudes.
- 47.66 Write an expression for a waveform comprising the fundamental with second and third harmonic components of specified amplitudes.

### **Probability**

- 47.67 Define probability ( $p$ ) and show that  $0 \leq p \leq 1$ .
- 47.68 Define complementary probability ( $q$ ) and show  $p + q = 1$ .
- 47.69 Calculate the values of probability in simple cases.
- 47.70 Define mutually exclusive events, independent events and dependent events.
- 47.71 Perform calculations related to simple cases of total and compound probability.
- 47.72 Define the classical probability  $P$  of an event  $A$  occurring as  $P(A) = n(A) / n(S)$ , where  $n(A)$  is the number of ways  $A$  can occur and  $n(S)$  is the total number of ways that possible events can occur.
- 47.73 Solve simple problems using the multiplication law for probability of independent events.
- 47.74 Solve simple problems using the addition law for probability of independent events.

# Assessment

## Test specification for written question paper 047 Advanced Mathematics

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** questions.

The examination paper will cover the knowledge specifications:

Topic	Approximate % examination weighting
Trigonometry	20
Geometry	
Algebra	
Complex numbers	10
Differential calculus	30
Integral calculus	
Differential equations and Laplace transforms	
Progressions and series	
Complex waveforms	10
Probability	10
Matrices and determinants	10

# 048 Computer Aided Draughting 2 Practical Assignments

## Introduction

The aim of this unit is to build on the elements of computer aided draughting acquired at diploma level and to introduce candidates to 3D construction, surface modelling and solid and regional modelling. Although this unit is based on AutoCAD version 12 plus the Advanced Modelling Extension (or later versions), centres may use any software having an equivalent specification.

## Practical competences

The candidate must be able to do the following:

### Co-ordinate systems

- 48.1 Use the UCS Command to define User Co-ordinate systems by all available methods, select a current UCS and delete a UCS.
- 48.2 Use the system variable THICKNESS to give an extrusion thickness to a 2D entity.
- 48.3 Use 3D points in absolute, relative and polar co-ordinates.

### 3D construction

- 48.4 Use 2D drawing entities on different User Co-ordinate Systems to produce 3D drawings.
- 48.5 Use the 3D drawing entities to produce 3D drawings.  
**Entities:** LINE, 3DPOLY, 3DFACE
- 48.6 Use the procedure for making the edges of 3D faces invisible.

### Surface modelling

- 48.7 Produce surfaced models using ruled surfaces, tabulated surfaces, surfaces of revolution, and edge-defined surface patches.  
**Surfaces:** RULESURF, TABSURF, REVSURF, EDGESURF
- 48.8 Use the system variables for the control of surface mesh density.  
**Variables:** SURFTAB1, SURFTAB2
- 48.9 Modify 3D drawings using 2D editing commands on different User Co-ordinate Systems.
- 48.10 Use the command PEDIT to fit a spline curve to a 3D polyline.
- 48.11 Edit the vertices of a polygon mesh created by a surface command PEDIT.
- 48.12 Use the command PEDIT to fit surfaces to polygon meshes.  
**Surfaces:** Bezier, quadratic b-spline, cubic b-spline

### Display control

- 48.13 Use the command PLAN to display a plan view of the current UCS, a named UCS and the World Co-ordinate System.
- 48.14 Use multiple view ports in the construction of a 3D drawing.  
**View ports:** VPORTS, VIEW PORTS
- 48.15 Select 3D viewpoints VPOINT to display a 3D model from various points in space.
- 48.16 Use the command DVVIEW to view a 3D model from various points in space.
- 48.17 Use the command DVVIEW to apply perspective projection to a 3D model.
- 48.18 Use clipping planes to create cut-away and section views of a 3D model – DVVIEW.
- 48.19 Vary the perspective view applied by using different lens values in the ZOOM option and in the DVVIEW command.
- 48.20 Perform hidden line removal on a 3D view of a drawing – HIDE.

### Blocks

- 48.21 Create blocks of 3D models – BLOCK.
- 48.22 Insert blocks of 3D models into drawings with any specified orientation in space INSERT.

### Solid modelling and materials selection

- 48.23 Create solid primitives.  
**Primitives:** box, cone, cylinder, wedge, taurus, sphere
- 48.24 Use solid commands to edit solid primitives.  
**Commands:** extrude, revolve, subtract, union, interfere
- 48.25 Apply editing commands to solid models.  
**Commands:** eg fillet, chamfer, scale
- 48.26 Assign appropriate materials to solid models and render. Save as GIF file.
- 48.27 Assign mass properties to the solid model and save as MPR file.

### Regional modelling

- 48.28 Construct a 2D regional drawing from a 2D constructed drawing.
- 48.29 Use solid commands to edit 2D regional models.  
**Commands:** extrude, revolve, subtract, union, interfere
- 48.30 Apply editing commands to regional models.  
**Commands:** eg fillet, chamfer, scale

48.31 Produce hidden view and wire frame view using PAPERSPACE.

**Plotting 3D drawings.**

48.32 Produce plots from 3D drawings including views with perspective and with hidden lines removed.

48.33 Produce plots from surface and solid models.

# 048 Computer Aided Draughting 2 Practical Assignments

## Practical assignment 048/1: 3D Construction and Visualisation – Computer

### 1 Competence reference

48.1-48.6, 48.7, 48.13-48.19, 48.20-48.22, 48.32

### 2 Preparation

#### 2.1 Location of test

The centre, under supervision.

#### 2.2 Requirements

An AutoCAD manual, a computer set up and running AutoCAD version 12 (or later version) with a mouse and a laser printer.

A copy of section 3 and sections 6.1, 6.2, 6.3, 6.4 and 6.5.1 and 6.5.2.

#### 2.3 Instructor notes

Candidates are required to produce an orthographic drawing of a computer (see section 6) and three 3D views of the computer (see sections 6.1, 6.2 and 6.3).

The time allowed for this assignment is 3 hours.

After the assignment is completed, hard copies of the three stored perspective view and the orthographic and 3D drawing must be produced for marking purposes with hidden lines removed. This can be done by either the instructor or candidate. If done by the candidate, the instructor must ensure no further changes or additions are made to the drawings.

### 3 Candidates' instructions

- 3.1 This assignment must be completed within three hours. In this assignment you are required to create a 3D model and various views of a computer.
- 3.2 Create a new drawing called COMPUTER using the default prototype drawing.
- 3.3 Set appropriate drawing limits.
- 3.4 Produce the model of the computer as shown in sections 6.1, 6.2, 6.3 and 6.4, according to the instructions given in section 6.5, using 3D faces and other appropriate techniques. Invisible edges must be used where 3D faces meet in order to produce the surface model of the computer similar to that shown in sections 6.1, 6.2, 6.3 and 6.4. Create the circular supporting pins (see paragraph 6.5.2) by giving an extrusion thickness to the entity.
- 3.5 Create the slots on the disk drive and the panel on the front of the computer as surface details using the overall dimensions provided. The particular sizes of the details on these features are left to your discretion (see paragraph 6.5.1).  
  
In a similar way create the features on the back panel of the computer as surface details using the provided dimensions (see paragraph 6.5.2).
- 3.6 Set three perspective views corresponding as closely as possible to those shown in sections 6.1, 6.2 and 6.3. Select an appropriate position for the 'clipping plane' used to show the internal details of the computer as shown in section 6.3.  
  
Save these views with the names VIEW-A, VIEW-B and VIEW-C respectively.
- 3.7 Plot or print plot the views to file, with hidden lines removed, with the names VIEW-A, VIEW-B and VIEW-C. Save the drawing using the name COMPUTER.
- 3.8 Set two new views showing the front view and side view of the computer illustrated in section 6.4. Using paperspace position these views together with a plan view of the original computer you created as shown in section 6.4.  
  
Enter your name on the drawing.
- 3.9 Save the orthographic drawing showing the three views of the computer using the name C2. Plot or print plot this drawing to file, with hidden lines removed, with the name C2.
- 3.10 Hand in your work to the instructor.

## 4 Marking

Marking must be carried out on both the hard copies and the stored drawing (see paragraph 2.3).

- 4.1 All entities present. [ ]
- 4.2 All entities on electronic file drawn to the correct size and with the correct orientation. [ ]
- 4.3 Supporting pins drawn with an extrusion thickness setting. [ ]
- 4.4 3D face edges invisible where appropriate. [ ]
- 4.5 A suitable perspective view, similar to that in section 6.1 selected. [ ]
- 4.6 A suitable perspective view, similar to that in section 6.2 selected. [ ]
- 4.7 A suitable perspective view, similar to that in section 6.3 selected. [ ]
- 4.8 A suitable 'clipping plane' selected for the view shown in section 6.3. [ ]
- 4.9 An orthographic drawing of the computer produced showing the elevations in the positions shown in 6.4. [ ]
- 4.10 Completed within three hours. ( )

Notes: In 4.4, a few minor edges inadvertently left in the drawing are acceptable. In 4.5 to 4.7, the perspective views selected by the candidate must have similar angles, distance and lens length as those shown in sections 6.1 to 6.3 but exact replicas are not necessary.

## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if success is recorded in all items marked with a [ ].

A period of at least seven days must elapse before an unsuccessful candidate may retake this assignment.

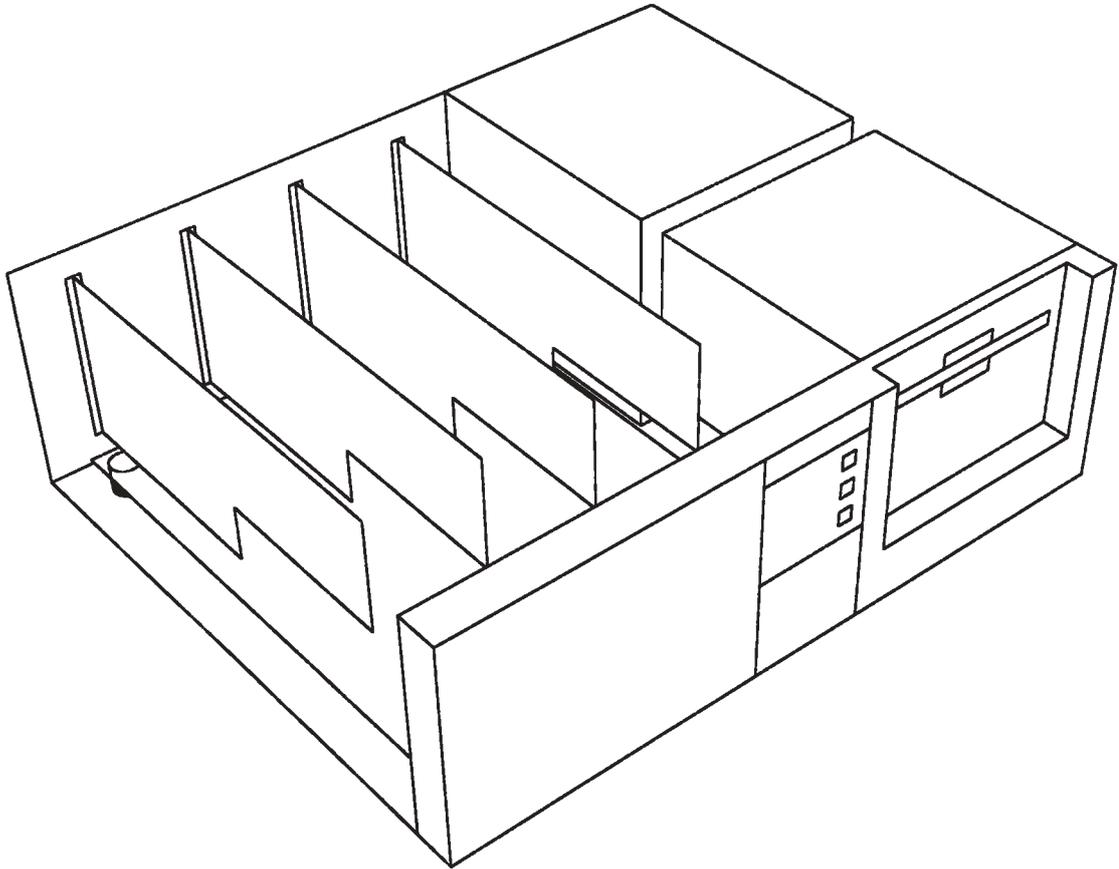
## 6 Assignment documentation

One complete set consisting of the following:

- 6.1 Required perspective drawing (View A)
- 6.2 Required perspective drawing (View B)
- 6.3 Required perspective drawing (View C)
- 6.4 Required orthographic drawing
- 6.5.1 Drawing instructions
- 6.5.2 Drawing instructions.

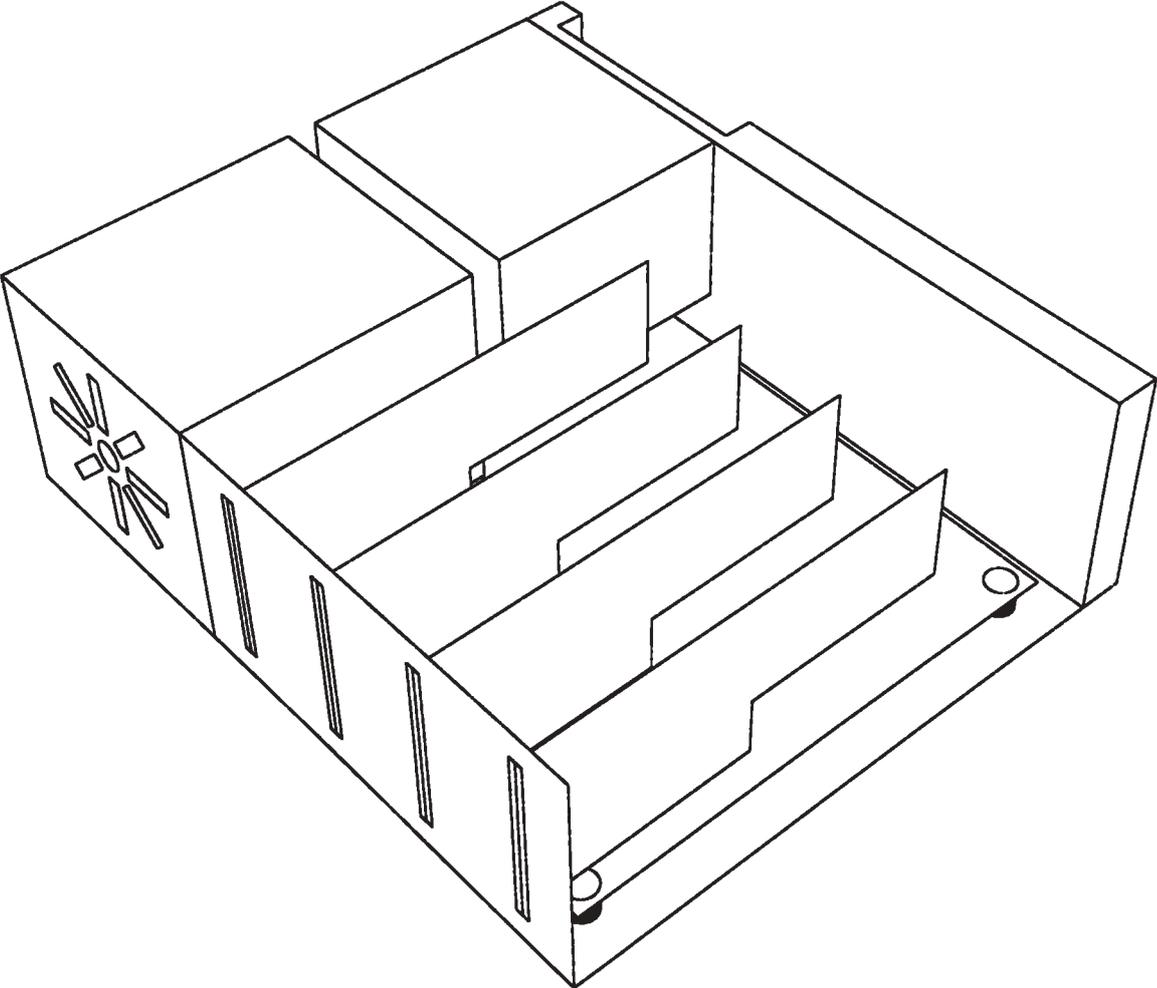
## 6 Assignment documentation

### 6.1 View A



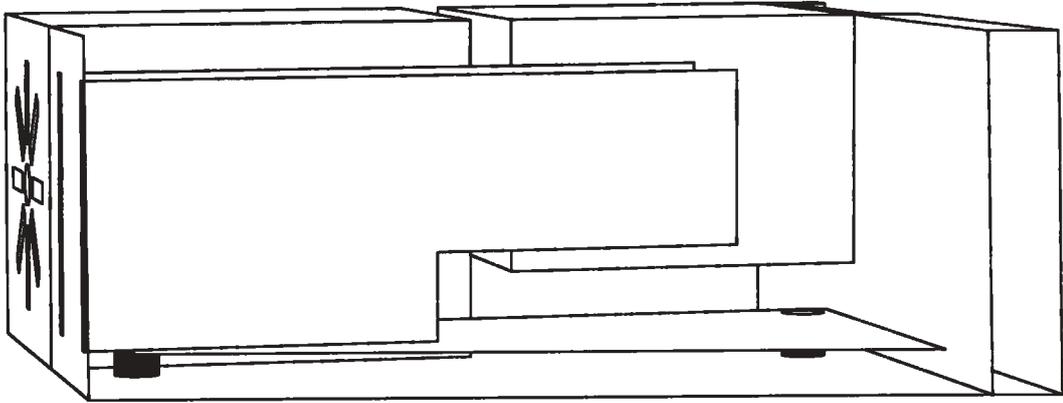
# 6 Assignment documentation

## 6.2 View B



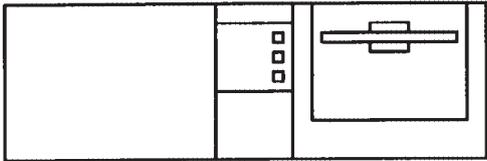
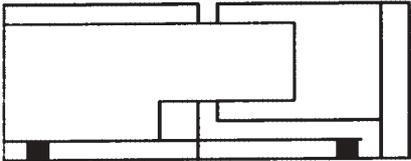
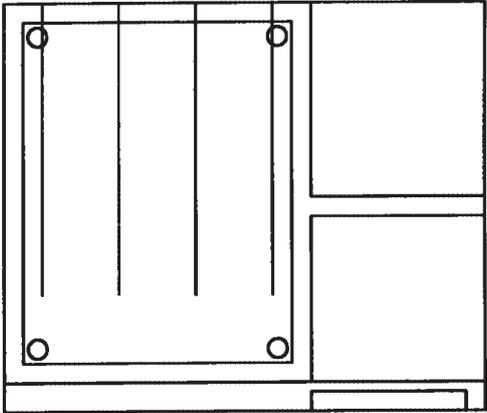
## 6 Assignment documentation

### 6.3 View C



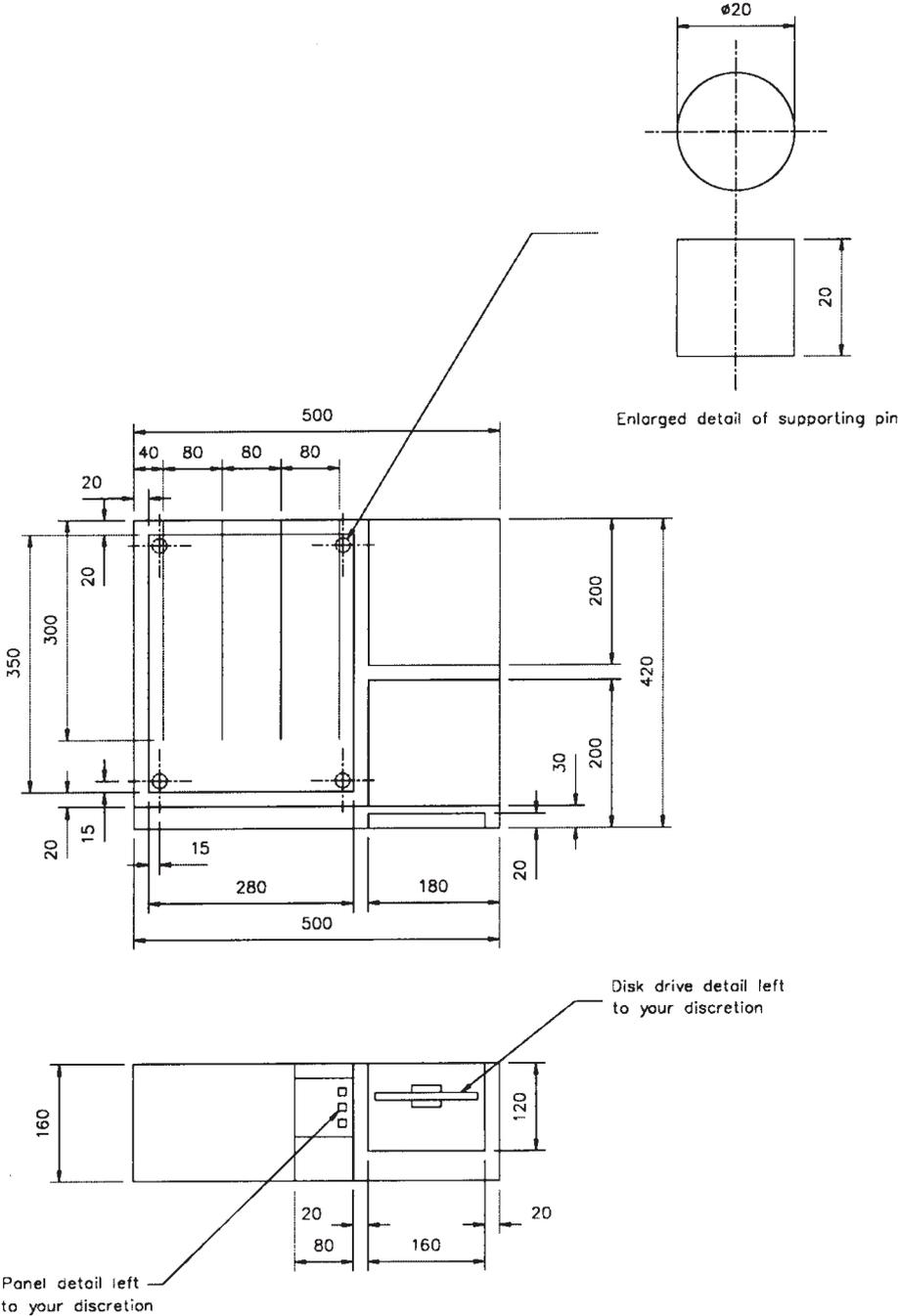
# 6 Assignment documentation

## 6.4 Orthographic drawing



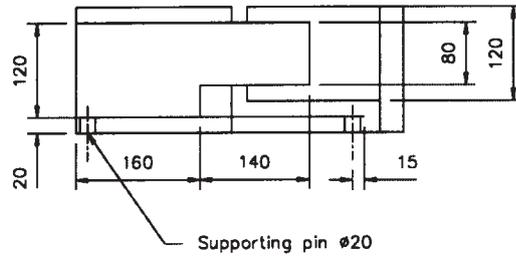
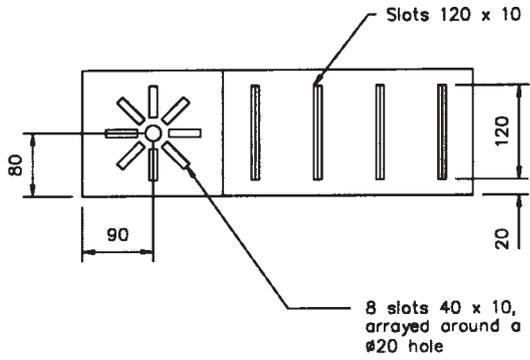
# 6 Assignment documentation

## 6.5.1 Drawing instructions



6 Assignment documentation

6.5.2 Drawing instructions



# 048 Computer Aided Draughting 2 Practical Assignments

## Practical assignment 048/2: Surface Modelling

### 1 Competence reference

48.1-48.4, 48.7-48.12, 48.13-48.15, 48.20, 48.33

### 2 Preparation

#### 2.1 Location of test

The centre, under supervision.

#### 2.2 Requirements

An AutoCAD manual, a computer set up and running AutoCAD version 12 (or later version) with a mouse and a laser printer. A copy of section 3 and sections 6.1 and 6.2.

#### 2.3 Instructor notes

Candidates are required to produce the surface model of the micrometer shown in section 6.1 according to the instructions given in section 6.2.

The time allowed for this assignment is three hours.

After the assignment is completed, hard copies of the stored view must be produced for marking purposes. This should show the 3D views of the object with hidden lines removed. This can be done by either the instructor or candidate. If done by the candidate, the instructor must ensure no further changes or additions are made to the drawings.

### 3 Candidates' instructions

- 3.1 In this assignment you are required to produce a surface model of a micrometer. You have 3 hours to complete this assignment.
- 3.2 Create a new drawing called MODEL using the default prototype drawing.
- 3.3 Set appropriate drawing limits for the object concerned.
- 3.4 Produce a surface model of a micrometer as shown in section 6.1 according to the instructions given in section 6.2. For some parts of the model, there may be several equally appropriate methods of generating the surface. Whichever method is used, a similar mesh density to that shown in section 6 should be used.
- 3.5 Enter your name on the drawing.
- 3.6 Set a 3D view corresponding as closely as possible with that shown in section 6.1. Save this view with the name VIEW-A.
- 3.7 Plot or print plot the view to file with the name MODEL-1. Save the drawing using the name MODEL.
- 3.8 Produce hard copy of the stored view showing the 3D views of the object with hidden lines removed. Hand it in to the instructor.

## 4 Marking

Marking must be carried out on both the hard copy and the stored drawing. Because there is more than one way of producing a 3D surface model, the results must be marked against the criteria of 4.2 to 4.4 and only compared with the view given in section 6.1 for general shape and mesh density.

- |     |  |     |
|-----|--|-----|
| 4.1 | All entities present.  | [ ] |
| 4.2 | The defining framework/basic structure is dimensionally correct.                   | [ ] |
| 4.3 | The types of surfaces used provide satisfactory representation of the shape shown. | [ ] |
| 4.4 | Mesh densities similar to those shown in section 6.1 used.                         | [ ] |
| 4.5 | A 3D-view, similar to that in section 6.1 selected.                                | [ ] |
| 4.6 | Completed within 3 hours.  | ( ) |

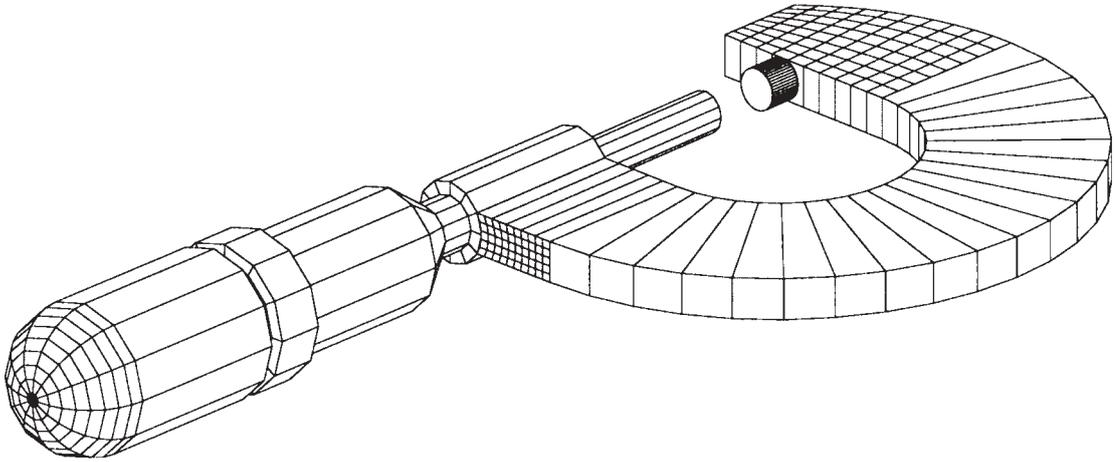
## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ] .

A period of at least seven days must elapse before an unsuccessful candidate may retake this assignment.

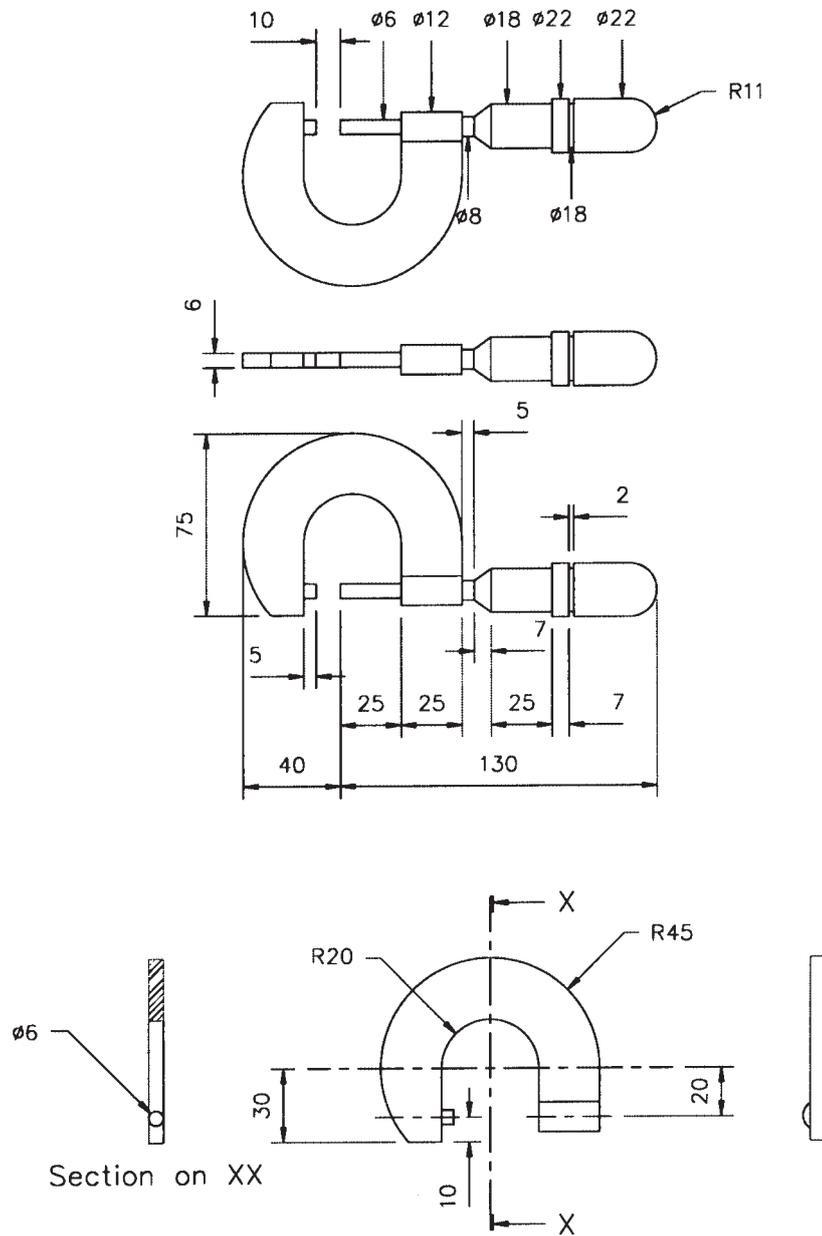
## 6 Assignment documentation

### 6.1. Required drawing



## 6 Assignment documentation

### 6.2 Drawing instructions



Detail of micrometer 'frame' assembly

# 048 Computer Aided Draughting 2 Practical Assignments

## Practical assignment 048/3: Solid Modelling – Flanged Pipe Coupling

### 1 Competence reference

48.23-48.27

### 2 Preparation

#### 2.1 Location of test

The centre, under supervision.

#### 2.2 Requirements

An AutoCAD manual, a computer running AutoCAD version 12 (or later version) with a mouse and a laser printer.

A copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to produce a solid model and two views (see section 6.1 and 6.2, view A, sliced view and view B, a sectional view) from an orthographic view of a flanged pipe coupling.

Instructors may either produce the orthographic view (see section 6.3) and give copies on disk or in user network area to candidates or require candidates to produce the orthographic view prior to the assignment.

The time allowed for this assignment is 3 hours.

### 3 Candidates' instructions

- 3.1 You are required to produce a solid model and two views (see section 6.1, view A, sliced view and section 6.2, view B, a sectional view) from an orthographic view of a flanged pipe coupling. You have 3 hours to complete this assignment.
- 3.2 Create a new drawing called COUPLING using the default prototype.
- 3.3 Set appropriate drawing limits.
- 3.4 Use profile drawing of sectional detail for the flanged coupling provided (see section 6).
- 3.5 Produce the solid model of flanged coupling from the drawing instructions (section 6.3).
- 3.6 Produce one of the sliced views on the required drawing as shown in view A. Save this view under the name VIEW-A.
- 3.7 Produce the sectional drawing and match view B. Save this new view with the name VIEW-B.
- 3.8 Apply materials bronze or copper to view A and render.
- 3.9 Save the rendered view as SOLID.GIF.
- 3.10 Print or plot view A and view B to file with the names VIEW-A and VIEW-B and also save the drawings.
- 3.11 Extract the mass properties of the sliced view, save as SOLID.MPR and print.
- 3.12 Hand in your work to your instructor.

## 4 Marking

- 4.1 Assignment completed in 3 hours. ( )
- 4.2 A new drawing called COUPLING created using the default prototype. [ ]
- 4.3 Appropriate limits set. [ ]
- 4.4 Profile drawing of sectional detail for flanged coupling used. [ ]
- 4.5 The solid model of flanged coupling produced from drawing instructions. [ ]
- 4.6 Sliced view on required drawing produced. [ ]
- 4.7 Sectional drawing produced and view B matched. [ ]
- 4.8 Materials, bronze or copper, applied to view A and rendered. [ ]
- 4.9 Rendered view saved as SOLID.GIF. [ ]
- 4.10 View A and view B printed or plotted. [ ]
- 4.11 Mass properties of the sliced view extracted, saved as SOLID.MPR and printed. [ ]
- 4.12 Work handed in to instructor. [ ]

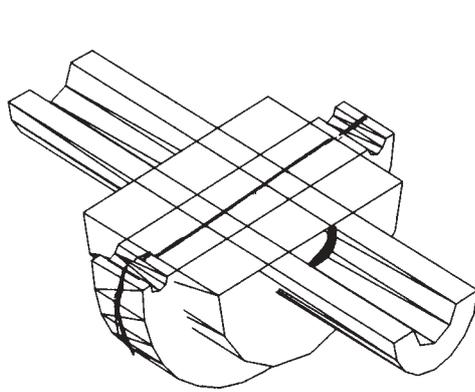
## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ].

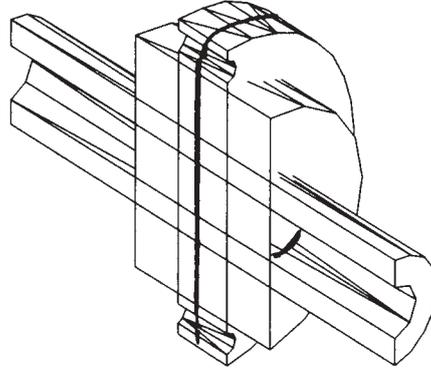
A period of several days must elapse before an unsuccessful candidate may retake this assignment.

## 6 Assignment documentation

### 6.1 Required drawing – View A



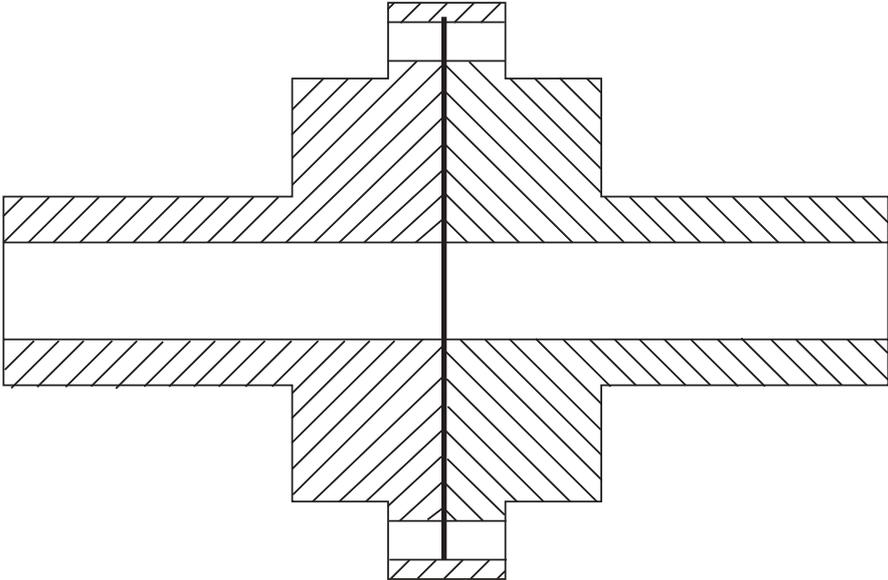
Sliced View (ROTATED AT 90 DEGREES)



Sliced View (SW ISOMETRIC)

## 6 Assignment documentation

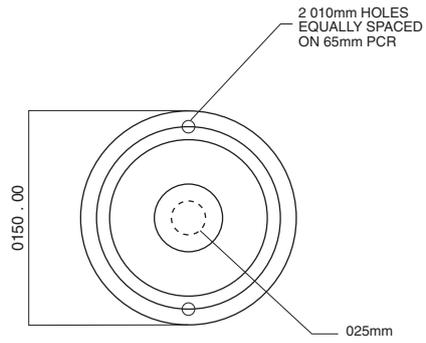
6.2 **Required drawing – View B:** Solid section view of flanged pipe coupling (after hatching)



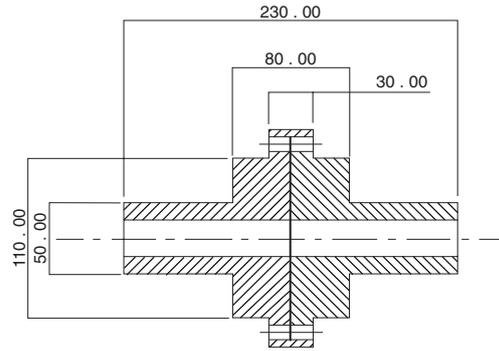
## 6 Assignment documentation

### 6.3 Drawing instructions

Instructions for flanged coupling



Sectional detail of flanged pipe coupling



# 048 Computer Aided Draughting 2 Practical Assignments

## Practical assignment: 048/4 Regional Modelling – Link Mount

### 1 Competence reference

48.28-48.31

### 2 Preparation

#### 2.1 Location of test

The centre, under supervision.

#### 2.2 Requirements

An AutoCAD manual, a computer running AutoCAD version 12 (or later version) with a mouse and a laser printer

A copy of section 3 and section 6.

#### 2.3 Instructor notes

Candidates are required to produce two views of a regional model of a link mount (see section 6, view A, south west isometric view and front elevation and view B, both south west elevations – one hidden, one wire framed).

Instructors may either produce the orthographic view (see section 6.3) and give copies to candidates on disk or user network area or require candidates to produce the orthographic view prior to the assignment.

The time allowed for this assignment is 31/2 hours.

### 3 Candidates' instructions

- 3.1 You are required to produce two views of a regional model of a link mount (see section 6, view A, south west isometric view and front elevation and view B, both south west elevations – one hidden, one wire framed). You have 31/2 hours to complete this assignment.
- 3.2 Create a new drawing called REGION.DWG.
- 3.3 Set appropriate drawing limits.
- 3.4 Use the orthographic profile of the link mount provided (see section 6.3).
- 3.5 Produce required drawing view A of south west isometric view and front elevation.
- 3.6 Produce required drawing view B of both south west elevations – one hidden, the other wire framed.
- 3.7 Print or plot view A and view B to file with the names VIEW-A and VIEW-B and also save the drawings.
- 3.8 Extract mass properties of both views, save as VIEWA.MPR and VIEWB.MPR and print.
- 3.9 Hand in your work to the instructor.

## 4 Marking

- 4.1 Assignment completed in 3 1/2 hours. ( )
- 4.2 A new drawing created called REGION.DWG. [ ]
- 4.3 Appropriate drawing limits set. [ ]
- 4.4 An orthographic profile of the link mount used. [ ]
- 4.5 Required drawing produced, view A of south west isometric view and front elevation. [ ]
- 4.6 Required drawing produced, view B of both south west elevations – one hidden, the other wire framed. [ ]
- 4.7 View A and view B printed or plotted and drawings saved to file. [ ]
- 4.8 Mass properties of both views extracted, saved as VIEWA.MPR and VIEWB.MPR and printed. [ ]
- 4.9 Work handed to the instructor. [ ]

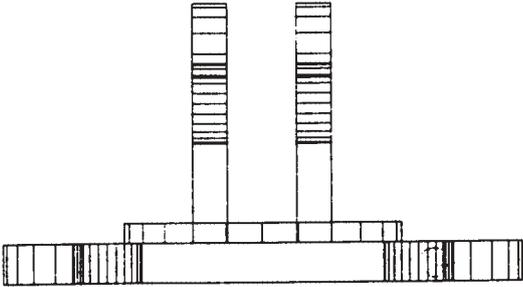
## 5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with [ ].

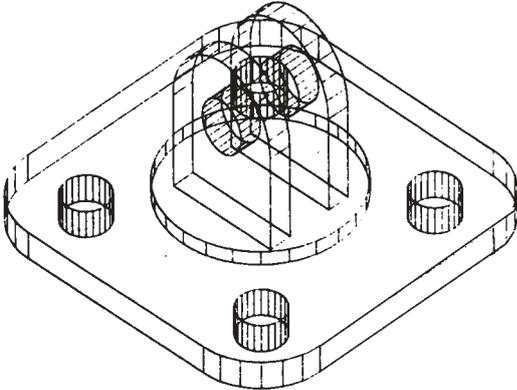
A period of several days must elapse before an unsuccessful candidate may retake this assignment.

# 6 Assignment documentation

## 6.1 View A



FRONT ELEVATION

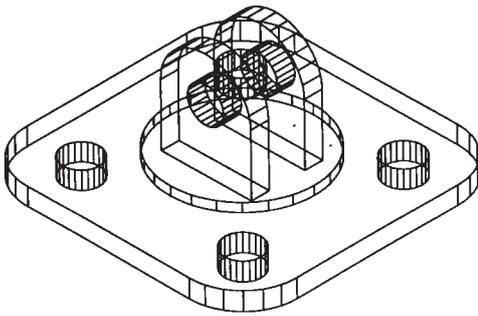


SOUTH WEST ISOMETRIC VIEW

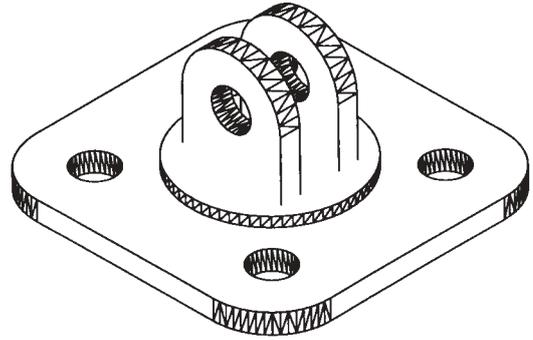
## 6 Assignment documentation

### 6.2 View B

REQUIRED DRAWING – LINK MOUNT



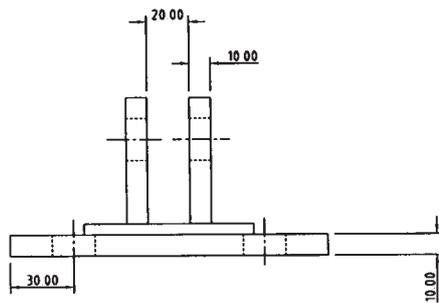
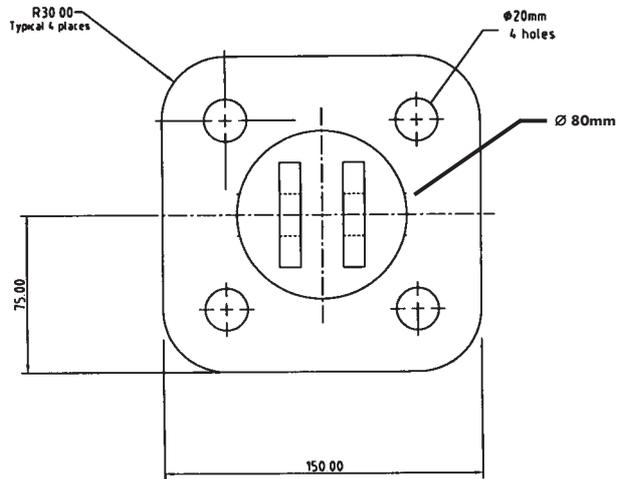
WIRE FRAMED MODEL



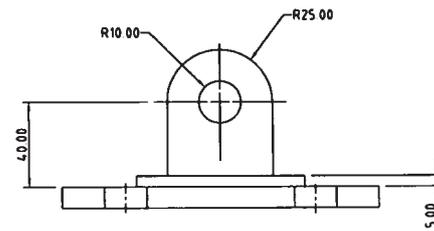
HIDDEN REGIONED MODEL

## 6 Assignment documentation

### 6.3 Drawing instructions



LINK-MOUNT



# Appendix A

## Practical assignments

Two assessment methods are used in the 2565 Technician Awards in Engineering programme – written questions and practical assignments.

### Practical assignments

Some of the units or components in the Advanced Diploma level of this programme have a related practical assignment or assignments. These assignments may call on skills covered in other sections but reference is only made to the competences covered by the marking criteria. Wherever relevant the option is given for you to use local names, local currencies, alternative measurements and paper sizes, or to design an alternative assessment. **Where this option is taken the assignment must be of a comparable standard** to ensure consistency between centres using this programme. The assignment must be documented and available for the visiting verifier. ALL assignments must be successfully completed.

The assignments may be administered at any time convenient to the instructor and to the candidate.

The practical assignments in this publication are intended to be photocopied.

### Instructor notes

It is essential that you read these before attempting to administer the practical assignment. Practical assignments usually require you to prepare material for the assignment.

### Candidate instructions

Make sure every candidate has a copy of these before beginning the practical assignment.

### Marking

The marking is based on performance criteria or outcomes related to the practical assignment, to which the answer will always be either 'yes – the candidate achieved this' or 'no – the candidate did not achieve this'. Credit is given for those performance competences for which the answer is 'yes – the candidate achieved this'.

### Supervision

All assignments require supervision and you must make sure that the results reflect only the individual candidate's own work. You must keep all assessment documentation and material in a file for each candidate until the results have been agreed by the visiting verifier and until confirmation of result has been received from City & Guilds.

### Records, results and certification

Successful completion of the related practical assignments for each unit needs to be recorded and then sent to City & Guilds. We suggest that you keep a record of each individual's achievements which may then be transferred to the entry forms. A model is given at the end of this section but you may use any form of record keeping that is convenient and accessible.

In order to gain certification, results for successfully completed practical assignments must be sent to City & Guilds. Results for practical assignments are entered onto Form S which is then countersigned by the visiting verifier and sent to us.

An advantage of this programme is that candidates who successfully complete the practical assignments for a single unit may, if they wish, claim a Certificate of Unit Credit. This may be beneficial for those candidates who only wish to complete part of this programme. Send these claims to us at any time provided the visiting verifier has countersigned the Form S.

Candidates wishing to gain the full award (Certificate, Diploma or Advanced Diploma) must successfully complete all the relevant practical assignments. We recommend that their practical results are sent at the time of, or shortly before, the date of the written examinations.

### Visiting verifier

The operation of this programme requires the appointment of a visiting verifier. The visiting verifier must countersign the results of the practical assignments on Form S. The visiting verifier should also be able to inspect records and candidates' work to verify the results before submission.

## Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Design & Manufacture

### Candidate assessment record

\*Candidates must complete these assignments

Candidate's name and number

---

Centre name and number

---

Assessment reference	Date completed	Instructor signature	Instructor name
030/1 Engineering project*			
035/1 Operate a CAM system*			
035/2 Write a programme*			
036/1 Portfolio production*			
036/2 Product specification and design*			
036/3 Redesign an existing Product*			
036/4 Pattern drawing*			
036/5 Design and draw a drill Jig*			
048/1 Construction and visualisation*			
048/2 Surface modelling*			
048/3 Solid modelling*			
048/4 Regional modelling*			

## Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Plant Technology

### Candidate assessment record

\*Candidates must complete these assignments

Candidate's name and number

---

Centre name and number

---

Assessment reference	Date completed	Instructor signature	Instructor name
030/1 Engineering project*			
036/1 Portfolio production*			
036/2 Product specification and design*			
036/3 Redesign an existing product*			
036/4 Pattern drawing*			
036/5 Design and draw a drill Jig*			
039/1 Steam gen. and power*			
039/2 Calculate heat transference*			
041/1 Hydraulic system*			
041/2 Pneumatic system*			
048/1 Construction and visualisation			
048/2 Surface modelling*			
048/3 Solid modelling*			
048/4 Regional modelling*			

## Advanced Technician Diploma in Applied Mechanical and Electrical Engineering – Control systems

### Candidate assessment record

\*Candidates must complete these assignments

Candidate's name and number

---

Centre name and number

---

Assessment reference	Date completed	Instructor signature	Instructor name
029/1 Wave shaping*			
029/2 Common emitter transistor amplifier*			
029/3 Intergrated circuit power amplifier*			
030/1 Engineering project*			
036/1 Portfolio production*			
036/2 Product specification and design*			
036/3 Redesign an existing product*			
036/4 Pattern drawing*			
036/5 Design and draw a drill Jig*			
048/1 Construction and visualisation*			
048/2 Surface modelling*			
048/3 Solid modelling*			
048/4 Regional modelling*			



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Published by City & Guilds  
1 Giltspur Street  
London  
EC1A 9DD  
T +44 (0)20 7294 2850  
F +44 (0)20 7294 2413  
intops@cityandguilds.com  
www.cityandguilds.com

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