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# INTRODUCTION TO DISTANCE LEARNING AND THIS MODULE

Distance Learning differs from the traditional method of learning that you will have used at school or college, where you work at a fixed rate that is determined by your teacher or lecturer. Their rate of teaching may be too fast or too slow for different students, so you either get bored or cannot keep up. Furthermore, if you miss a lesson, you will have to catch up before the next lesson, or you will quickly fall behind.

Distance Learning is not a new concept and has been around for several decades and it allows you to work at your own pace and in your own time. The Institute of Materials Finishing has been offering their courses for many years and after listening to our students, we realised that the preferred method of teaching was by offering scripted lecture notes.

Although you will be often working alone in your studies, the Institute makes sure that you have enough support if and when you have any problems.

In this latest revision of our courses, each lesson is a self-contained and complete unit.

As you are aware, you have been allocated an 'Industrial Counsellor' who, hopefully, is a member of your company. One of the roles of the Industrial Counsellor is to help you understand what you are being taught. We fully accept that non-one will fully understand every part of their course the first time they see it. Every person is different and has different skills and attributes, so they will find different parts of the course either easy or more difficult. When you meet a difficulty, you should ask the Industrial Counsellor to help you; it is their role to help you to understand the content of the lessons. If a suitable person is not immediately available within your company then the Institute will have made arrangements for you to be linked to a suitable local member of the Institute who has agreed to be available to assist you. Even if this person cannot immediately answer your problem, he or she will know someone who can. Most importantly, do not become disheartened in your studies. If, on any occasion, your Counsellor is unable to help, you should contact Education Manager at The IMF's Head Office who will arrange for a Professional Member to contact and assist you.

You will find it very useful to have a pencil or pen and paper with you when you are studying, as you can quickly write down any extra notes or explanations; these can be very useful when you come to revising or are seeking further help.

This module is made up from a set of lessons of various lengths that are composed of written text with some illustrations where relevant. You may need to read the text several times to fully understand it and before moving on to the next lesson.

There is a series of different tasks set throughout the text; these are headed SAQs, SMAs and MAs.

### **SAOs - Self Answered Questions**

SAQ's are questions relating to what you have just studied. Their purpose is to check that you have understood the lesson so far. Firstly, you should try to answer the question without checking back through your notes and then check your answer with the model answer provided at the end of the Lesson. If your answer is correct, you should continue with the next part of the lesson. If, however, you are unable to answer the question or have incorrectly answered the question, we suggest you go over the section again and get a better understanding of the lesson.

### **SMA – Self Marked Assessment**

SMA's are usually found at the end of a lesson, but by no means every lesson. They are a series of questions that you should try to answer. The questions will be relevant to the lessons that you have just studied and there will be four or five possible answers for each question. You should identify which one you think is correct and when you have completed the series of questions, you should check your answers against those given at the end of the lesson. You will also find a short explanation explaining why each answer is correct or incorrect.

These SMAs, as both questions and answers, are also included in Appendix 1 and can be a useful source of revision prior to your examination.

### **MA –Marked Assignment**

You will be expected to carry out a series of 4 assignments during your studies. These will cover some of the Module's objectives and are designed to test your understanding of the study material and that you can use the knowledge gained to suggest answers to specific problems or situations. In the traditional system of learning, this may have been called 'homework'.

You will find detailed instructions on how to carry out the assignments in Appendix 2. Please pay particular attention to the information regarding **plagiarism** and make sure you fully understand it and the consequences of plagiarism

After completing each assignment, it should be sent to the Institute to be externally marked. (NOTE Students on tutored courses will have their assignments marked by their tutor.) Once marked, it will be returned to you. The total marks you receive for the four assignments contribute up to a maximum of 20% towards your final examination mark, so you are rewarded for your efforts.

**Please note: marked assignments are compulsory and must be submitted by the due date for you to be eligible for the final examination. This is fully explained in Appendix 2 and Appendix 5.**

### **The Examination**

Your examination will last for 2 hours and the examination paper consists of two sections:

**Section A** 5 short essay questions, all of which should be attempted, for which it is suggested you should allow about 30 minutes in total for your 5 answers.

**Section B** consists of 8 longer essay questions, of which you should attempt five; it is suggested that you allow about 15 minutes for each answer.

Section A gives a maximum of 25% of your total marks and Section B gives 75% of your total marks for the examination. Your answer papers will be marked by an external examiner of the Institute and the examiner's mark will be moderated by the Institute's Examination and Qualifications Board (EQB).

The pass mark is 40%. This is made up from both your marks for your MA's as well as the marks you obtain in the final examination.

A mark of 60% and over gives a '**Pass with Merit**' whilst a mark of over 75% gives a '**Pass with Distinction**'. If you achieve these marks, the credit will be shown on your certificate. (An average mark of at least 40% must be obtained for the 4 assignments for a merit or distinction to be awarded)

**NOTE:** Candidates whose first language is not english may use a dictionary book during the examination, other types of dictionary, e.g. electronic ones and technical dictionaries, are not permitted. The examination's invigilator will check that the dictionary is suitable before the start of the examination. (Examples of suitable dictionaries are standard english dictionaries and dictionaries providing translation from english to another language and vice versa.)

### **Additional Distance Learning Modules**

There are additional modules of a similar academic standard. These are:

- Principles of Electroplating
- Electroplating Practice
- Powder Coating
- Environmental, Health and Safety
- Paint, Lacquer & Varnish OR Automotive Surface Finishing
- Materials Science

Any one of the above, combined with the module you have just completed, can lead to the award of a '**Technician Certificate**'. The benefit here is that you can apply for the professional qualification '**Technician of the Institute of Materials Finishing**' and the insignia **TechIMF**, with which you can apply for the international award from the UK Engineering Council of '**Engineering Technician**' and the insignia **EngTech**, which is internationally recognised across all industries.

After the successful completion of 4 Technician modules, one of which must be the Environmental, Health and Safety module, you will be awarded an Advanced Technician Certificate.

# OBJECTIVE SYLLABUS FOR ELECTROFORMING MODULE

## SECTION A – INTRODUCTION TO ELECTROFORMING

### Lesson 1 What is electroforming?

At the end of Lesson 1, you should be able to:

- 1.1 Define electroforming.
- 1.2 Understand why electroforming is a valuable manufacturing process.
- 1.3 List some applications of electroforming.

### Lesson 2 Why Electroplating is Used as a Coating Method

At the end of Lesson 2 you should be able to:

- 2.1 Explain why electroplating is such a popular way of putting metal coatings onto substrates.
- 2.2 Deduce what properties of a plated coating should be specified so that the plated part should be suitable for a certain use.
- 2.3 List the main processes in a typical plating sequence.
- 2.4 State why it is so important to rinse the parts in water after different processes

## SECTION B – GENERAL PRINCIPLES OF ELECTRODEPOSITION

### Lesson 3 Basic Electrodepositing Circuits and Calculations

At the end of Lesson 3 you should be able to:

- 3.1 List the main components of an electrodepositing electrical circuit and draw the associated circuit diagram.
- 3.2 Know the parameters and their units for the control of the electrical supply to an electrodeposition tank.
- 3.3 Calculate the operating parameters associated with the electrical supply to an electrodeposition tank.

## **Lesson 4    Chemical Symbols and Chemical Equations**

**At the end of Lesson 4 you should be able to:**

- 4.1    Write the chemical symbols for the chemicals used most often in electroplating and electroforming
- 4.2    Write chemical equations for simple chemical reactions.
- 4.3    Understand how atoms join together by ionic, covalent and metallic bonds.

## **Lesson 5    Electrode Reactions in Electroforming**

**At the end of Lesson 5 you should be able to:**

- 5.1    Explain the difference between a homogeneous and a heterogeneous reaction.
- 5.2    Identify an electrochemical reaction
- 5.3    List different types of cathode reduction reactions

## **Lesson 6    Electrode Reactions and Faraday's Law**

**At the end of Lesson 6 you should be able to:**

- 6.1    Identify different anodic reactions
- 6.2    List problems of secondary cathodic reactions
- 6.3    Understand the effect of imbalance of cathode and anode efficiencies
- 6.4    Recognise a Faradaic Reaction and know how its rate can be measured.

## **Lesson 7    Electrode Reactions and Deposition Rate**

- 7.1    List the factors affecting the rate of a Faradaic Reaction.
- 7.2    Understand what makes a reaction take place and what causes the reactants to reach the surface.
- 7.3    Understand why there are limits to the maximum plating rate
- 7.4    Understand that substances adsorbed onto a cathode surface can affect electrodeposition

## **Lesson 8    Electrodepositing Alloys and Composites**

**At the end of Lesson 8 you should be able to:**

- 8.1    Understand how the electrodeposition of alloys occurs.
- 8.2    Understand how processing parameters influence the composition of the deposited alloy.
- 8.3    Know the difference between an alloy deposit and a composite coating. Understand how the co-deposition of particles can enhance the properties of an electroformed metal artefact.

## **SECTION C – ELECTROFORMING ELECTROLYTES**

## **Lesson 9 Electroforming with nickel**

**At the end of Lesson 9 you should be able to:**

- 9.1 Prepare and use a Watts nickel type electroforming solution.
- 9.2 Prepare and use a sulphamate nickel electroforming solution.
- 9.3 Prepare and use a Ni-speed nickel electroforming solution.
- 9.4 Appreciate the benefits of codepositing cobalt with nickel when electroforming.
- 9.5 Appreciate how the addition of organic compounds can modify the properties of nickel deposits.
- 9.6 Understand that embrittlement of nickel deposits may occur if sulphur is incorporated in the deposit.

## **Lesson 10 Electroforming with iron, chromium, copper, silver and gold**

**At the end of Lesson 10 you should be able to:**

- 10.1 Discuss the different types of solution used for electroforming iron.
- 10.2 Discuss the advantages and disadvantages of the different types of copper electrolytes used for electroforming.
- 10.3 Describe the formulations of the different types of copper electroforming solution.
- 10.4 Describe how to use silver electroforming solutions.
- 10.5 Discuss the advantages and disadvantages of the different types of gold electrolytes used for electroforming.
- 10.6 Describe formulations for the deposition of gold alloy electroforms.

## **SECTION D – THE MEASUREMENT AND CONTROL OF THE PROPERTIES OF ELECTROFORMS**

### **Lesson 11 Some important properties of electroformed metals and their measurement**

**At the end of Lesson 11 you should be able to:**

- 11.1 Understand what is meant by tensile strength and how it is measured.
- 11.2 Understand what is meant by ductility and how it is measured.
- 11.3 Understand what is meant by hardness and how it is measured.
- 11.4 Understand what is meant by internal stress and how it is measured.
- 11.5 Appreciate the importance of controlling internal stress in electroforms.
- 11.6 Discuss the structure of nickel deposits and how additives and deposition parameters influence the structure of electrodeposits.

### **Lesson 12 The Influence of electrodeposition parameters on the properties of electroformed metals**

**At the end of Lesson 12 you should be able to:**



- 12.1 Discuss how the mechanical properties of nickel deposited from Watts type solutions are affected by changes in operating parameters and solution composition.
- 12.2 Discuss how the mechanical properties of nickel deposited from sulphamate solutions are affected by changes in operating parameters and solution composition.
- 12.3 Appreciate how the amount of cobalt in a nickel-cobalt deposit affects the mechanical properties of the deposit.
- 12.4 Appreciate how organic additives to nickel electroforming solutions are used to modify the mechanical properties of nickel electroforms.
- 12.5 Discuss how the mechanical properties of copper deposits vary with the type of electroforming solution used.
- 12.6 Appreciate how the mechanical properties of copper deposits can be modified by changes to electrolyte composition and operating parameters.
- 12.7 Appreciate how the mechanical properties of alloy gold deposits change vary with their gold content

### **Lesson 13 Process Control and the Hull Cell**

**At the end of Lesson 13 you should be able to:**

- 13.1 Explain the meaning of Process Control.
- 13.2 Explain the benefits of Process Control.
- 13.3 Keep a log of an Electroforming Process.
- 13.4 Use a Hull cell.
- 13.5 Appreciate what a Hull cell test can show.
- 13.6 Appreciate some Hull cell test applications.
- 13.7 List common faults that can occur when electroplating.
- 13.8 Identify sources of contamination which affect product quality.
- 13.9 Know how to remove contamination from electroforming solutions.

## **SECTION E – MANDRELS AND PHOTORESISTS**

### **Lesson 14 Mandrels**

**At the end of Lesson 14 you should be able to:**

- 14.1 Understand the function of a mandrel.
- 14.2 Appreciate the difference between permanent and non-permanent mandrels.
- 14.3 Know the materials that can be used for permanent mandrels.
- 14.4 Know the materials that can be used for non permanent mandrels.
- 14.5 Know how to make a non conductive mandrel conductive.
- 14.6 Know how to design a mandrel.
- 14.7 Know how to prepare a mandrel for electroforming.

### **Lesson 15 Photoresists and basic processing**

**At the end of Lesson 15 you should be able to:**

- 15.1 Understand the difference between positive and negative photoresists.
- 15.2 Know the basic sequence for exposing photoresists.

- 15.3 Know about the different light sources used for exposing photoresists.
- 15.4 Know about photomasks and their exposure.
- 15.5 Know how to develop photoresists.
- 15.6 Know how to develop photoresists.

## **Lesson 16 Types of photoresist**

- 16.1 Appreciate the advantages and disadvantages of negative and positive photoresists.
- 16.2 Know of the different types of liquid film photoresist.
- 16.3 Know the different methods for applying liquid film photoresists
- 16.4 Appreciate the advantages and disadvantages of dry film photoresists.
- 16.5 Know how dry film photoresists are applied and developed.
- 16.6 Understand how electrophoretic photoresists are applied.

## **SECTION F – PLANT, EQUIPMENT AND SERVICES FOR ELECTROFORMING**

### **Lesson 17 Plant and equipment for electroforming**

**At the end of Lesson 17 you should be able to:**

- 17.1 Select process tanks.
- 17.2 Discuss the operation of power supplies and rectifiers.
- 17.3 Appreciate how pulse plating techniques work.
- 17.4 Select busbars for power distribution to the process solutions.
- 17.5 Discuss different types of filtration for process solutions.
- 17.6 Discuss the selection of pumps and their use.
- 17.7 List common faults that can occur when electroplating.
- 17.8 Know about the different methods of solution agitation.
- 17.9 Select and use techniques for heating process solutions.

## **Lesson 18 Anodes for electroforming solutions**

**At the end of Lesson 18 you should be able to:**

- 18.1 Discuss the use of titanium anode baskets.
- 18.2 Correctly bag anodes.
- 18.3 Describe and select the different types of anode available for nickel electroforming.
- 18.4 Describe and select the different types of anode available for copper electroforming.
- 18.5 Describe and select the different types of anode available for gold and silver electroforming.
- 18.6 Discuss the use of inert (insoluble) anodes.

## **Lesson 19 The treatment and disposal of electroforming wastes**

**At the end of Lesson 19 you should be able to:**

- 19.1 Discuss how the discharge of hazardous effluents can cause danger, damage or loss.
- 19.2 List the main hazardous wastes from electroforming.
- 19.3 Explain how heavy metal ions can be removed by alkaline precipitation and flocculation.
- 19.4 List the main methods for disposal of cyanides.
- 19.5 Discuss how to minimise the amounts of waste produced.
- 19.6 Explain the principles of ion-exchange and its application to effluent treatment.
- 19.7 Discuss the concept that valuable materials can be recovered from effluent streams.
- 19.8 List alternatives to precipitation for recovery or removal of metal ions from effluent streams.
- 19.9 Discuss methods for reducing water usage.
- 19.10 Identify how energy is wasted.

## **Lesson 20 Water chemistry, utilities and prime services**

**At the end of Lesson 20 you should be able to:**

- 20.1 Appreciate the meaning and purpose of utilities and prime services in the Electroforming Shop.
- 20.2 Realise the importance of water and know what it is.
- 20.3 Be aware of the properties of water.
- 20.4 Know about the treatment of water.
- 20.5 Be aware of the quality of deionised water.
- 20.6 Appreciate the value of water as a heat transfer fluid for cooling and heating.
- 20.7 Understand the key properties of utilities and services.
- 20.8 Be knowledgeable of the Factory Coding System.

## **SECTION G – HEALTH, SAFETY AND ENVIRONMENTAL ISSUES IN ELECTROFORMING**

### **Lesson 21 Health, safety and environmental legislation**

**At the end of Lesson 21 you should be able to:**

- 21.1 Understand what is required of an employer under the Health & Safety at Work Act (1974).
- 21.2 Understand what is required of an employee under the Health & Safety at Work Act (1974).
- 21.3 Be aware of the requirements of the Control of Substances Hazardous to Health Regulations (COSHH).
- 21.4 Understand the need for and the principles of risk assessments and their relevance to COSHH and the Health and Safety at Work Act.
- 21.5 Be aware of the use of pictograms and Hazard and Precautionary phrases for identifying the hazards of Hazardous Substances.
- 21.6 Be aware of REACH.
- 21.7 Be aware of the main environmental legislation concerning permits, waste and pollution of water.
- 21.8 Be aware of other legislation that may affect the processes used in surface finishing.

### **Lesson 22 Health and safety hazards and precautions**

**At the end of Lesson 22 you should be able to:**

- 22.1 List and identify the most important items of safety equipment in a surface finishing department.
- 22.2 Identify the most common hazards to be found in the workplace.
- 22.3 Be aware of the most common chemical hazards.
- 22.4 Identify the principal hazards in the electroplating shop.
- 22.5 Be aware of specialist hazards to be found in other types of surface finishing areas.
- 22.6 Know how to avoid any short and long term effects of these hazards.
- 22.7 Discuss the importance and role of training in the prevention of accidents.
- 22.8 Know how to avoid a fire and to mitigate its effects.

### **Lesson 23 Nickel and health**

**At the end of Lesson 23 you should be able to:**

- 23.1 Discuss how nickel causes an allergic reaction.
- 23.2 Be aware of the regulations concerning the use of nickel.
- 23.3 Know about ‘nickel itch’ and how to avoid it.

## **SECTION H – ELECTROFORMING CASE STUDIES**

### **Lesson 24 Nozzle Plate and Inkjet Printer heads**

**At the end of Lesson 24 you should be able to:**

- 24.1 Appreciate why electroforming is used for the manufacture of inkjet printer heads.
- 24.2 Discuss the electroforming sequence for inkjet printer heads.
- 24.3 Appreciate the required design steps to obtain the correct hole diameters in the inkjet printer head.

### **Lesson 25 Electroforming foils and meshes**

**At the end of Lesson 25 you should be able to:**

- 25.1 Prepare a permanent mandrel for the electroforming of meshes and foils.
- 25.2 Discuss the electroforming of meshes with a permanent mandrel.
- 25.3 Prepare a semi-permanent mandrel for the electroforming of meshes and foils.
- 25.4 Discuss the electroforming of foils for electric razors .

### **Lesson 26 MEMS and NEMS applications of electroforming**

**At the end of Lesson 26 you should be able to:**

- 26.1 Appreciate the scale of MEMS and NEMS device and the difficulties of working at this scale.
- 26.2 Discuss the manufacture of MEMS and NEMS devices.
- 26.3 Discuss examples of electroformed MEMS and NEMS devices.

### **Lesson 27 Electroforming of moulds and dies**

**At the end of Lesson 27 you should be able to:**

- 27.1 Appreciate the range of moulds and dies that are electroformed.
- 27.2 Discuss the types of mandrel used for moulds and dies.
- 27.3 Discuss the techniques developed for the electroforming of large moulds and dies.

### **Lesson 28 Stampers**

**At the end of Lesson 28 you should be able to:**

- 28.1 Know how to electroform vinyl record stampers.
- 28.2 Know how to electroform compact disc stampers.
- 28.3 Know how to electroform hologram stampers.

### **Lesson 29 Medical prostheses and dentistry**

**At the end of Lesson 29 you should be able to:**

- 29.1 Discuss the electroforming of dental crowns and bridges.
- 29.2 Appreciate some of the techniques used for the electroforming of medical prostheses.
- 29.3 Appreciate the use of MEMS and LIGA techniques for the manufacture of miniature prostheses.

## **Lesson 30 Jewellery**

**At the end of Lesson 30 you should be able to:**

- 30.1 Discuss applying an electric current to thin metallic coatings by the technique known as 'ramping'.
- 30.2 Electroform delicate objects.
- 30.3 Electroform items of jewellery.

## **Lesson 31 Electrojoining**

**At the end of Lesson 31 you should be able to:**

- 31.1 Appreciate the benefits and disadvantages of electrojoining.
- 31.2 Produce effective joints by electrojoining.

## **Lesson 32 The Prince of Wales Coronet**

**At the end of Lesson 32 you should be able to:**

- 32.1 Discuss the electroforming of the gold coronet.

## **Lesson 33 Additive Manufacturing – a disruptive technology?**

**At the end of Lesson 33 you should be able to:**

- 33.1 Understand how Additive Manufacturing works.
- 33.2 Discuss the treats and opportunities offered by Additive manufacturing.
- 33.3 Provide advice on alternative manufacturing techniques.

## **Lesson 34 New Materials and Technologies**

**At the end of Lesson 34 you should be able to:**

- 34.1 Be aware of some new materials that may affect the future of surface coatings
- 34.2 Have an understanding of graphene.
- 34.3 Be aware of conducting polymers.