# IFE Level 3 Diploma in Fire Science and Fire Safety (VRQ)

## Unit 1: Fire Engineering Science

**Unit Reference Number: A/505/6005**

### Introduction

This unit focuses on fire engineering science and fire behaviour. The content of the unit has been designed to reflect the critical technical knowledge that fire professionals need in order to understand the behaviour of fire and the mechanics of firefighting equipment. This knowledge and understanding will contribute to increased safety on the incident ground.

### Learning Outcomes

Candidates who achieve this unit should be able to:

- Interpret data and carry out relevant calculations
- Understand and apply the scientific principles that underpin fire behaviour and the management of fires

### Unit Status

This is a mandatory unit for candidates who wish to achieve the Level 3 Diploma in Fire Science and Fire Safety.

### Fire Engineering Science Formulae

A list of Fire Engineering Science Formulae is provided at the end of this document. The formulae have been taken from the Fire Engineering Science Formula Booklet which is available on the *Preparing for Examinations* page of the IFE's website.

A copy of this formula list will be provided for candidates taking the Level 3 Diploma Fire Engineering Science examination along with the examination paper so candidates will have access to the list during the examination. Please note that candidates will not be able to take their own copy of the formula sheet into the examination but will be able to use the sheet provided by the IFE.

# Content

## 1. Analysis and Interpretation of Data

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 1.1 Extract and tabulate data | Expression of data in the form of:<br>• Graphs including histograms, bar charts, pie charts<br>• Tables |
| 1.2 Obtain values from data | Identify/Calculate:<br>• Median<br>• Mean<br>• Norm values |
| 1.3 Extend graphs | • Project values from given data (extrapolate)<br>• Deduce values from missing data (interpolate) |

## 2. Mechanics

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 2.1 Define and apply the SI system of units in terms of basic and derived units | • Recognise and use SI units for calculation and expressing values |
| 2.2 Describe and carry out calculations involving equations of motion | • Describe and apply Newton's laws of motion |
| 2.3 Understand and solve calculations involving vectors | • Use vector quantities to find resultant values<br>• Apply vector methods to force and motion problems |
| 2.4 Calculate moments around a fulcrum including the use of levers and parallel force | • Definition of "fulcrum"<br>• Definition of "moment"<br>• Methods of calculation |
| 2.5 Carry out calculations involving centres of gravity and centres of buoyancy | • Definition of "centres of gravity"<br>• Definition of "centres of buoyancy"<br>• Methods of calculation |
| 2.6 Carry out calculations involving stress and strain | • Definition of stress strain<br>• Understand and apply Hooke's Law of elasticity |
| 2.7 Carry out calculations involving work, power and efficiency | • Understand and apply the definitions of:<br>o Work<br>o Power<br>o Efficiency<br>o Force<br>o Momentum<br>o Mass<br>o Weight |
| 2.8 Describe and calculate friction force between two surfaces in contact | • Definition of "friction"<br>• Methods of calculation |

## 3. Hydraulics

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 3.1 Define and solve problems involving density, specific gravity and pressures in fluids | • Define the terms density, specific gravity and pressures in fluids<br>• Understand and apply the definitions of velocity, acceleration and energy<br>• Demonstrate the relationship between the terms<br>• Methods of calculation |
| 3.2 Understand and apply the principle of atmospheric pressure in pumping systems | • As an aid to flow<br>• As a means of measuring flow<br>• Definition of "atmospheric pressure" and methods of measuring it |
| 3.3 Understand and apply the laws of friction to calculate energy losses in piped water supplies | • Laws of friction<br>• Methods of calculation<br>• Operation of piped water supplies |
| 3.4 Understand and explain the operation of pumps and carry out calculations | • Definition of water power<br>• Definition of brake power<br>• Definition of efficiency<br>• Types of calculation required and methods of calculation |
| 3.5 Explain the relationship between velocity and discharge of water through hose of differing diameters | • Methods of calculating velocity, flow and quantity of water in hose and pipelines of differing diameters |
| 3.6 Explain the purpose and principles of design of siphons, branches and nozzles | • Purpose of nozzles and siphons<br>• Design and operating principles of nozzles<br>• Design and operating principles of siphons<br>• Methods of calculating discharge from a nozzle |
| 3.7 Calculate the theoretical and the effective height of a jet | • Methods of calculation<br>• Significance of difference in specific gravities between different liquids |

## 4. Electricity

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 4.1 Understand the theory of electrical current flowing in a circuit and apply this | • Define the terms "electron" and "current"<br>• Describe electric current as a flow of electrons<br>• Describe how electrical energy is generated and distributed<br>• Describe the characteristics of alternating and direct current<br>• Define the following: Volts, Amperes, Ohms, Watts, Joules<br>• Methods of calculating current, power, voltage, energy and resistance |

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|---|---|
| 4.2 Describe the operation and characteristics of a step-up and step-down transformer | • Principles of operation of a transformer<br>• Methods of calculation |
| 4.3 Explain and use Ohm's Law | • Principles of Ohm's Law<br>• Use Ohm's Law to solve problems<br>• Calculate the relationship between resistance, current and voltage in simple parallel and series circuits |
| 4.4 Explain the magnetic and chemical effects of electrical currents | • Show how these phenomena are applied in:<br>a) Electric motors<br>b) Primary and secondary electric cells |
| 4.5 Describe the function and method of operation of circuit protective devices | Types to include:<br>• Residual Current Device (RCD)<br>• Miniature circuit breakers (MCB)<br>• Fuses |
| 4.6 Define and solve problems involving resistance variation | • Temperature<br>• Resistivity<br>• Methods of calculation |
| 4.7 Apply the concept of power to electrical circuits | • Power formula<br>• Methods of calculation |

## 5. Heat and Energy

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 5.1 Explain and apply the principles of heat transfer | • Methods of heat transfer<br>• Definition of:<br>o Absolute zero<br>o Specific heat capacity<br>o Latent heat<br>o Thermal capacity of a body<br>• Methods of calculation |
| 5.2 Calculate linear, superficial and volumetric expansion using the relevant coefficients | • Definition of linear, superficial and volumetric expansion<br>• Understand and use coefficients |
| 5.3 Apply the Gas Laws to calculations involving changing conditions of heat | Define and use Gas Laws:<br>• Boyle's Law<br>• Charles's Law<br>• Law of Pressures (also known as Gay-Lusacc's Law)<br>• Combined Gas Law |
| 5.4 Explain the principles of the electromagnetic spectrum | • Wavelength and intensity<br>• Effect on materials<br>• Effect on the human body |

## 6. Radioactivity

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 6.1 Describe the principle of radioactivity | • Explain the terms:<br>o Radioactivity |

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| | ○ Radiation<br>• Define the terms “decay” and “half life” |
| 6.2 Describe the biological effects of radiation and precautions to be adopted for safety from the effects of radiation | • Explain the construction and properties of alpha and beta particles and gamma radiation and compare their penetrating powers<br>• Effects on cells<br>• Methods of contamination<br>• Principles of protection from ionising radiation |

## 7. Chemistry

| Assessment Objective | Knowledge, Understanding and Skills |
|---|---|
| 7.1 Describe the construction of an atom and show how the electron shell configuration has an effect on reactivity | • Definition of “reactivity”<br>• Components of an atom – protons, neutrons, electrons, shell |
| 7.2 Demonstrate an understanding of the classifications of the chemical elements and the main hazards associated with each grouping | • Structure of the Periodic Table of Elements<br>• Classification of elements into Metals and Non-metals<br>• Properties of elements:<br>○ Reaction to heat<br>○ Reaction to electricity<br>○ Physical form in different situations<br>○ Reaction with oxygen<br>○ Reactivity<br>• Explain the concept of valency and the relevance of the periodic classification of the elements |
| 7.3 Understand and use chemical equations | • Balance simple chemical equations and define stoichiometric conditions<br>• Calculate relative molecular masses and vapour densities from given relative atomic masses<br>• Use “balanced” chemical reactions for the calculation of the masses and the volumes, of reactants in chemical reactions |
| 7.4 Explain the main properties, reactions and hazards of specified elements, compounds and groups | • Acids (inorganic and organic)<br>• Bases and Alkalis<br>• Ammonia<br>• Calcium Oxide<br>• Ammonium hydroxide<br>• Carbon monoxide<br>• Carbon dioxide<br>• Chlorine<br>• Hydrogen<br>• Oxygen<br>• Sodium<br>• Sulphur<br>• Phosgene |
| 7.5 Explain the properties of hydrocarbons | • Composition of hydrocarbons - hydrogen and carbon |

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| | • Structure and main properties of the first four members of the alkane family<br>  ○ Methane, ethane, propane and butane<br>  ○ Properties – density, boiling point and melting point<br>• Structure of simple unsaturated hydrocarbons (alkenes and alkynes)<br>• Structure and properties of aromatic compounds<br>• Structure and properties of alcohols, aldehydes and ketones |
| 7.6 Define the terms flashpoint, fire point and spontaneous ignition temperatures | • Definition of "flashpoint"<br>• Definition of "fire point"<br>• Definition of "spontaneous ignition temperatures" |
| 7.7 Apply the principles of chemistry to the extinction of fire | • Principles involved in the extinction of fire by:<br>  ○ Smothering<br>  ○ Cooling<br>  ○ Oxygen starvation<br>• Understand that a combustion is a type of chemical reaction<br>• The principle and components of the fire tetrahedron and the inhibition of combustion chains involving a free radical mechanism<br>• Principle of free radicals |
| 7.8 Explain the properties of oxidising agents | • Oxygen<br>• Halogens<br>• Inorganic and organic oxidising agents<br>• Peroxide |
| 7.9 Explain the properties of polymers | • Define "monomer" and "polymer"<br>• Explain the polymerisation process<br>• Thermosetting and thermoplastic materials<br>• Fire hazards |

## 8. Principles of Heat and Combustion Sensitive Detection Devices

| **Assessment Objective** | **Knowledge, Understanding and Skills** |
|---|---|
| 8.1 Explain the operating principles of heat and combustion sensitive detection devices | • Types of device:<br>  ○ Ionisation detectors<br>  ○ Optical detectors<br>  ○ Heat detectors<br>  ○ Combustion detectors<br>  ○ Radiation detectors<br>  ○ Flame detectors<br>• Use and effectiveness of the detectors listed above according to the risk to be covered and their reliability |
| 8.2 Explain and apply the principles of thermocouples and thermistors | • Explain the use of thermocouples<br>• Explain the use of thermistors |

# L3D1 - Fire Engineering Science Formulae Sheet

| | | |
|---|---|---|
| $v = u + at$ | $s = \frac{(u+v)}{2}t$ | $s = ut + \frac{1}{2}at^2$ |
| $v^2 = u^2 + 2as$ | $s = vt - \frac{1}{2}at^2$ | $F = m \times a$ |
| $P = \mu R$ | $P - F_r = 0$ | $R - F = 0$ |
| $P = \frac{F \times d}{t}$ | $Efficiency = \frac{useful\ output\ power}{input\ power}$ | |
| $W = Pt$ | $W = Fd$ | $KE = \frac{1}{2}mv^2$ |
| $PE = mgH$ | $v = \sqrt{2gH}$ | $P = \rho gH$ |
| $P = \frac{H}{10}$ | $P_f = \frac{9000flL^2}{d^5}$ | $L = \frac{2}{3}d^2\sqrt{P}$ |
| $WP = \frac{100LP}{60}$ | $E = \frac{WP}{BP} \times 100$ | $R = 0.157Pd^2$ |
| $V = IR$ | $P = IV$ | $R = \frac{\rho l}{a}$ |
| $R_T = R_1 + R_2 + R_3$ | $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ | $R_t = R_0(1 + \alpha t)$ |
| $c = \frac{\Delta Q}{m \times \Delta t}$ | | $\frac{R_0}{R_t} = \frac{1 + \alpha_0 t_{ref}}{1 + \alpha_0 t_{final}}$ |
| $L_{Exp} = l \times \propto \times \Delta T$ | $A_{Exp} = A \times 2 \propto \times \Delta T$ | $V_{Exp} = V \times 3 \propto \times \Delta T$ |
| $P_1 \times V_1 = P_2 \times V_2$ | $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ | $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ |
| $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ | $PV = nRT$ | |

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| $A = \pi r^2$ or $A = \frac{\pi d^2}{4}$ | $A = \pi r^2$ x depth or $A = \frac{\pi d^2}{4}$ x depth | |
| $A = \frac{\pi d^3}{6}$ or $A = \frac{4\pi r^3}{3}$ | $A = \frac{area\ of\ base \times vertical\ height}{3}$ | |
| $a^2 + b^2 = c^2$ | $C = \frac{2}{3} \times surface\ area \times average\ depth$ | |
| K = °C + 273 | °C = K – 273 | $V = \frac{1}{3}\pi r^2 h$ |
| $A = \pi r l$ | $V = \frac{4}{3}\pi r^3$ | $A = 4\pi r^2$ |
| $V = \pi r^2 h$ | $A = 2\pi r h$ | $A = \frac{1}{2}(a + b)h$ |
| $A = \frac{1}{2}ab \sin C$ (m²)<br>$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$<br>$a^2 = b^2 + c^2 - 2bc \cos A$ | | |
| $V = area\ of\ cross - section \times length$ | | |
| $adj = hyp \times \cos\theta$ or $\sin\theta = \frac{opp}{hyp}$<br>$opp = hyp \times \sin\theta$ or $\cos\theta = \frac{adj}{hyp}$<br>$opp = adj \times \tan\theta$ or $\tan\theta = \frac{opp}{adj}$ | | |