IFE Level 4 Certificate in Fire Science and Fire Safety

Unit 1: Fire Engineering Science

Unit Reference Number: Y/505/5931

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 behaviour of materials and substances. This understanding will contribute to increased safety on the incident ground.

Learning Outcomes

Candidates who achieve this unit should be able to:

- understand and apply the scientific principles that underpin fire behaviour and the management of fires
- apply understanding of combustion, fire dynamics and the effects of heat to explain issues and solve problems
- apply scientific understanding of special hazards and hazardous materials to explain issues and solve problems

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 4 Certificate 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.

Unit Status

This is a mandatory unit for candidates who wish to achieve the Level 4 Certificate in Fire Science and Fire Safety.

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Content

1. Mathematics

Assessment Objective	Knowledge, Understanding and Skills
1.1 Understand the underpinning mathematics required for fire engineering science Note: Examination papers will not contain questions on pure mathematics but this section indicates the mathematical techniques that candidates will require when dealing with the science.	• Understand the order of operations of mathematical terms (BODMAS) • Transposition of formulae • Circles, Triangles and Angles • Sine, Cosine and Tangent • Graphs and data tables, interpolating, extrapolating data • Range, Mode, Median and Mean • Scalar and vector quantities and calculation methods • Recognise and use SI units for calculation and expressing values • Recognise and use scientific notation (standard form) with numbers

2. Hydraulics

Assessment Objective	Knowledge, Understanding and Skills
2.1 Explain the principles of, and carry out, energy calculations	• Total Energy (Bernoulli) Equation • Continuity Equation
2.2 Describe, and carry out calculations in relation to, flow of water in pipes and open channels	• Turbulent flow • Laminar flow • The Venturi effect • Operating principles of siphons • Operating principles of weirs
2.3 Explain how Venturi meters, Pitot tubes and weirs are used to evaluate flow rates, pressure and pressure drops	• Carry out calculations for flow rate using the Venturi meter • Calculate the flow of water through open channels, rectangular weirs and vee notch weirs
2.4 Calculate forces exerted by a jet hitting a flat or inclined surface	• Jet hitting a flat surface • Jet hitting inclined surface • Formula for calculating jet reaction

3. Combustion

Assessment Objective	Knowledge, Understanding and Skills
3.1 Describe and explain a flame or combustion in terms of chemical reactions and analyse the factors which influence the speed of the reaction	Understand and apply the definitions of: • Limits of flammability • Diffusion flames • Premixed flames

	• Cold flames • Self-ignition temperature
3.2 Describe and explain combustion and the combustion reaction process	Define terms: • Spontaneous heating • Spontaneous ignition • Spontaneous combustion • Chain mechanism • Effects of temperature and pressure on rate of reaction • Ignition processes • Combustion of solids, liquids, gases, transient dust and vapour phases • Dust and spray explosions
3.3 Describe how the combustion process can be terminated	Explain the principles involved in the extinction of fire by: • Smothering • Cooling • Oxygen starvation
3.4 Explain the process and effects of oxidation	• Define the term oxidation • Identify examples of high temperature oxidation processes • Hazards of flammable materials that contain their own means of oxidation

3.5 Explain the range and behaviours of explosives	• Differentiate between high and low explosives
	• Classifications of explosives:
	  ○ Detonators
	  ○ Propellants
	  ○ Initiators
	  ○ Deflagrators

4. Fire Dynamics

Assessment Objective	**Knowledge, Understanding and Skills**
4.1 Understand the incubation and ignition stages of a fire	• Materials • Thermal inertia • Radiative heat transfer to fuel surfaces
4.2 Understand the early growth stage of a fire	• Surface spread of flame (wind aided/wind opposed) • Floors/walls/stairs/trench effect • Fuel array geometry • Radiative spread • The effects of fire position (centre of room/near wall/in corner), ceiling height
4.3 Understand the impact of heat in a fire	• Release rate/square metre of material/item/whole fire • Fire calorimetry
4.4 Understand flame and smoke plumes	• Flame height versus heat release • Plume height • Cold air entrainment

	• Basic smoke movement • Ceiling layer formation • Layer temperature versus radiant
4.5 Understand ventilation	• Bi-directional flow through an opening • Ventilation control of fires in compartments • Layer formation • Smoke outflow through an opening

4.6 Understand fire development in compartment fires	• Thermal properties of wall and ceiling materials
	• Flashover:
	  o Definition
	  o Heat release rates and conditions for flashover
	  o Time to flashover
	  o Growth prior to flashover
	  o Fully developed fire post-flashover
	• Backdraught (or smoke explosion):
	  o Definition
	  o Conditions for backdraught
	• Sketch a fire growth curve for a compartment fire showing incipient, developing, flashover, fully developed fire and decay phases

4.7 Understand fire growth rates	• Time squared fires (slow/medium/fast/ultra fast) • Factors affecting the growth of fire
4.8 Understand the steady state phase	• Duration of burning and fire load (Laws' Law)
4.9 Understand the decay phase	• Effect of fuel or air depletion • Automatic/manual extinction

5. Effects of Heat

Assessment Objective	Knowledge, Understanding and Skills
5.1 Explain the production of heat by the following processes	• Friction • Combustion of gases • Passages of electric current • Chemical reactions
5.2 Explain the effects of fire and heat on structural materials	Structure materials to include: • Timber • Brick • Stone • Reinforced concrete • Cast iron • Steel • Aluminium • Glass
5.3 Understand the principles of laboratory tests which may be used to assess materials and elements of structure	• Flammability • Fire resisting properties

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5.4 Understand the factors which influence the severity of a fire within a room or building	• Fire Load • Fire Load Density • Calculations using calorific values
5.5 Apply the Gas Laws to calculations involving changing conditions of heat	Define and use Gas Laws: • Boyle's Law • Charles's Law • Law of Pressures (also known as Gay-Lusacc's Law) • Combined Gas Law

6. Electricity

Assessment Objective	**Knowledge, Understanding and Skills**
6.1 Explain in detail the principles of electrical energy	• Generation • Transmission • Distribution • Utilisation • Generation, storage and discharge of static electricity
6.2 Explain the principle of protective measures utilised to safeguard individuals and equipment in conjunction with electrical energy	• Earthing • Bonding • Earth fault loop • Earth fault loop impedance • Protective arrangements for the use of electricity in atmospheres that are flammable or contain explosive dusts • Precautions necessary to minimise the generation, accumulation and discharge of static electricity particularly in flammable atmospheres
6.3 Explain and use Ohm's Law	• Principles of Ohm's Law • Use Ohm's Law to solve problems • Calculate the relationship between resistance, current and voltage in simple parallel and series circuits
6.4 Explain and use Kirchhoff's Law	• Principles of Kirchhoff's Current Law – the conservation of electric charge using node theory • Principles of Kirchhoff's voltage law – the sum of the voltages in a closed loop network equals zero

6.5 Carry out calculations involving electrical energy	• Power
	• Current
	• Voltage
	• Inductance
	• Capacitance
	• Impedance
	    o Resistance
	    o Inductive reactance

	○ Capacitive reactance ○ Admittance ○ Susceptance ○ Conductance • Simple RLC series and parallel circuits involving resistors, capacitors, inductors and AC/DC power supplies in combination • Power factor correction

7. Special Hazards

Assessment Objective	**Knowledge, Understanding and Skills**
7.1 Explain the methods of storage of hazardous substances and assess safety implications	• Internal and external storage • Hazardous materials which are: ○ Flammable ○ Toxic ○ Corrosive ○ Radioactive ○ Combination of hazards
7.2 Understand the effects of hazardous substances	• Physiological effects of hazardous substances • Effects of toxicity • Means by which toxic material can enter the body
7.3 Describe the nature, properties, industrial processes, the precautions to be taken in handling and storage, the signs and symptoms of poisoning, the flammability of the substances used in the process, the correct medical treatment to be applied, their reaction to firefighting media and to other substances and hazards of substances	• Fats and waxes • Paints and varnishes • Coal and coke • Petroleum spirit and fuel oils • Liquefied petroleum gases • Cellulose materials • Plastics • Metals • Animal and vegetable oils • Radioactive materials • Cryogenic substances • Explosives • Organic Solvents
7.4 Explain the hazards associated with energy materials	• Coal gas and natural gas installations • Petroleum and oil installations • Chemical plants • Liquefied petroleum gas installations • Pipelines convey flammable gas or liquids

L4C1 – Fire Engineering Science Formula Sheet

$v = u + at$	$s = \frac{(u+v)}{2}t$	$s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$	$s = vt - \frac{1}{2}at^2$	$F = m \times a$
$P = \mu R$	$P - F_r = 0$	$R - F = 0$
$P = \frac{F \times d}{t}$	$W = Pt$	$W = Fd$
$KE = \frac{1}{2}mv^2$	$PE = mgH$	$P = \rho gH$
$v = \sqrt{2gH}$	$V_{rms} = I_{rms}Z$	$P_{Avg} = I_{rms}V_{rms}\cos\theta$
$P = I^2R$	$Q = I^2X$	$S = I^2Z$
$R_T = R_1 + R_2 \dots R_n$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \dots \frac{1}{R_n}$	$c = \frac{\Delta Q}{m \times \Delta t}$
$L_T = L_1 + L_2 \cdots L_n$	$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} \cdots \frac{1}{L_n}$	$X_L = 2\pi fL$
$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \cdots \frac{1}{C_n}$	$C_T = C_1 + C_2 \cdots C_n$	$X_C = \frac{1}{2\pi fC}$
$V_s = \sqrt{V_R^2 + (V_L - V_C)^2}$	$I_s = \sqrt{I_R^2 + (I_L - I_C)^2}$	$Y = \frac{1}{Z}$; $G = \frac{1}{R}$; $B = \frac{1}{X}$
$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$Y = \sqrt{G^2 + (B_L - B_C)^2}$	$\frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$
$PF = \cos\theta$	$PF = \frac{R}{Z}$	$\theta = \cos^{-1}\left(\frac{R}{Z}\right)$
$L_{Exp} = l \times \propto \times \Delta T$	$A_{Exp} = A \times 2 \propto \times \Delta T$	$V_{Exp} = V \times 3 \propto \times \Delta T$
$P_1 \times V_1 = P_2 \times V_2$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

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$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	$PV = nRT$	$Q_1 = Q_2$
$P_1 + \rho g H_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g H_2 + \frac{1}{2}\rho v_2^2$		$A_1V_1 = A_2V_2$
$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$		$Q_1 = A_1V_1$
$m = \frac{A}{P}$	$H_f = \frac{2flv^2}{Dg}$	$P_f = \frac{20flv^2}{d}$
$F = \rho v^2 A$	$F = \rho v^2 A\, cos\theta$	$Q = vA$
$v = C\sqrt{mi}$	$Q = \frac{2}{3} CL\sqrt{2g}\, H^{1.5}$	$Q = \frac{8}{15} Ctan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{2.5}$
$\text{Sin}\,\theta = \frac{opp}{hyp}$	$\text{Cos}\,\theta = \frac{adj}{hyp}$	$\text{Tan}\,\theta = \frac{opp}{adj}$