IFE Level 4 Certificate in Fire Safety and Fire Science

Unit 1 – Fire Engineering Science

Examiner Report – March 2017

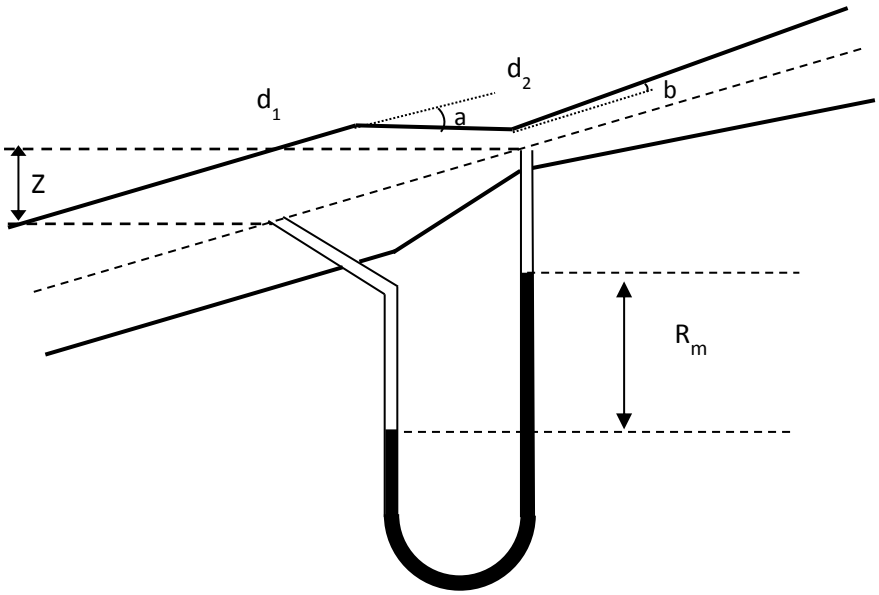
Introduction

The examination paper appeared to present challenges for candidates and results were generally poor. Candidates should be aware that Level 4 assessments are set at a level above A Level (Level 3) standard and therefore candidates are required to demonstrate and apply technical understanding at a high level.

Candidates often presented only limited responses and failed to demonstrate depth of understanding. Some candidates reproduced diagrams that were given in the question where this was not required; marks are available only for responses to questions and therefore candidates are advised not to spend time on tasks (such as re-drawing diagrams) that will not attract marks as they have not been specified in the question.

Candidates generally performed best on questions 3 and 7. However, even on these questions, few candidates attained more than 8 marks for their response to the question.

Question 1



a) Describe the operation of a Venturi meter. Include in your answer the significance of the angles "a" and "b" in the diagram above. (6 marks)

b) The Venturi meter above has an entrance diameter of 30cm (d_1) and a throat diameter of 20cm (d_2). The height between d_1 and d_2 (Z) is 250mm. The Venturi meter is used in the

process of evaluating the volume of gas flowing through a pipe. Note that the meter is positioned at an angle to the horizontal.

Use Bernoulli's equation to calculate the actual volume of gas flowing when the pressure difference between the entrance and the throat is measured as 6cm on a water U-tube manometer. The discharge coefficient of the apparatus is 0.96 and the density of the gas in the pipe is 2kgm^{-3}.(14 marks)

Examiner Feedback

This question required knowledge of the operating principles of a Venturi meter. Candidates generally understood the Bernoulli principles that underpin the operation but often failed to summarise this using appropriate scientific terms. A Venturing meter is a tool for measuring flow rates of fluids in pipes. The significance of angles a and b was not well understood. Angle a is large in order to achieve the reduced pressure in a short space, whereas angle b is more shallow in order to reduce turbulence.

The calculation of flow rate required the application of the standard Bernoulli formula. Candidates who were able to manipulate the formula by applying standard mathematical rules generally scored well but many failed to achieve this. Some candidates tried to utilise an incorrect formula which was not taken from the formula sheet provided. The question clearly stated that Bernoulli's equation should be used in the calculation. The discharge coefficient is an indication of the efficiency of the Venturi meter; it should only have been applied to the final theoretical flow rate.

Question 2

In order for a weir to function, it must create an energy change sufficient to make the flow pass through the critical point.

a) *Explain the meaning of the term "critical point". Include in your explanation the effect on depth of the liquid around the critical point. (10 marks)*

b) *Explain why V notch weirs are used to measure small discharges in favour of rectangular weirs. (4 marks)*

c) *Calculate the head of water needed above a V notch weir to produce a flow rate of 2.58 x 10^4 L/min if the notch angle is 80^o and the discharge coefficient of the weir is 0.62 (correct to 2 decimal places). (6 marks)*

Examiner Feedback

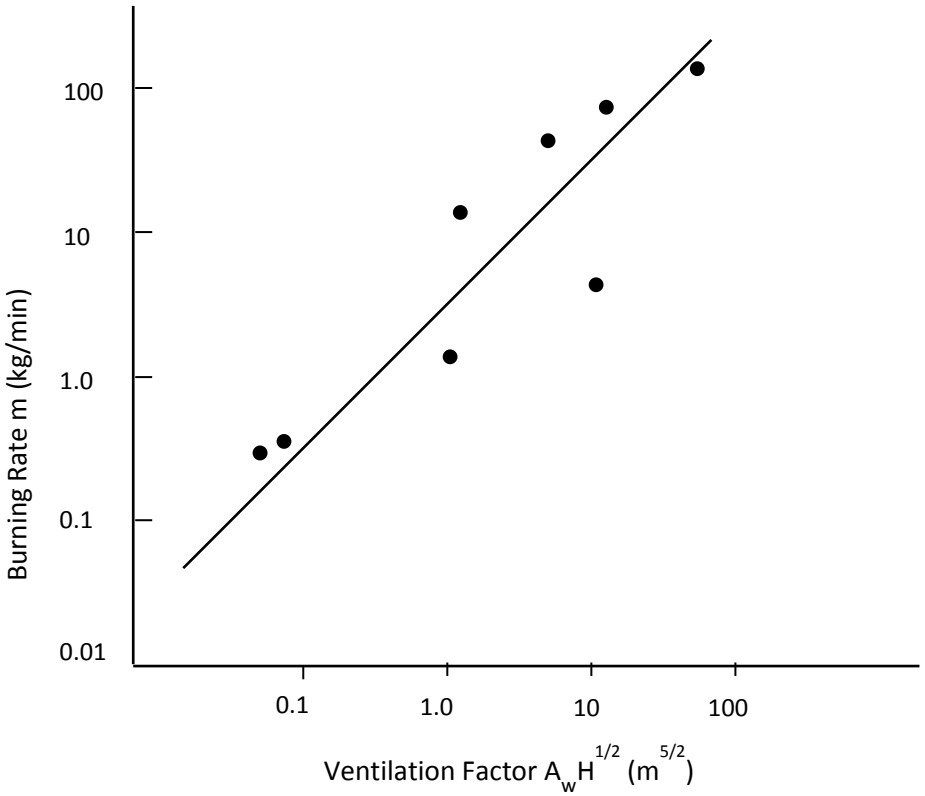
Few candidates appeared to have studied the theory behind a V-notch weir and therefore many were unable to provide a detailed explanation of the term 'critical point'. Many assumed that this referred to a physical part of the V notch, rather than it being a transitional

point between two states of flow. Marks were gained for demonstrating an understanding of sub and super critical flow around the critical point.

The calculation required candidates to be familiar with the correct formula on the formula sheet and then transpose it to find 'H'. This proved problematic for many. A common mistake was placing H inside the square root bracket. Many candidates also failed to convert the flow rate given to si units by dividing by 60,000 before using the value in the equation.

Question 3

The graph below shows the empirical relationship between the mass burning rate of cribs in a compartment and the ventilation factor of that compartment.



a) Use the line of best fit to approximate (to 1 decimal place) the equation that describes this relationship. (3 marks)

b) What are A_w and H in the equation? (2 marks)

c) Write the equation in SI units. (2 marks)

d) The relationship above holds true whilst the fire is "ventilation controlled". Explain the meaning of the term "ventilation controlled" fire. (4 marks)

e) *Beyond an upper limit, the fire becomes independent of the ventilation factor and is mainly governed by two different factors. What are they and how do they affect mass burning rate? (5 marks)*

f) *Explain in terms of energy why the heat released from a given mass of vehicle tyres is greater than that for the same mass of paper. (4 marks)*

Examiner Feedback

Very few candidates recognised this question as being a simple straight line graph of the form y=mx+c, where m (gradient) could be found by measuring the gradient on the graph. C is the intercept point of the line, which was near zero in this case. Aw represents the area of the window opening and H the height of the window.

Candidates' explanations of a ventilation controlled fire generally lacked depth of scientific knowledge and instead seemed to reply on operational experience. Candidates generally gained higher marks for their explanation of the chemistry underpinning the heat release rate from burning car tyres.

Question 4

a) *Use the example of rags soaked in linseed oil to explain spontaneous heating. (5 marks)*

b) *Under what specific conditions will spontaneous ignition occur? (6 marks)*

c) *The process of oxidation can be described in a number of ways. Consider the rusting of iron in the atmosphere to form iron (III) oxide. Write a balanced equation for this process and use it to give one definition of oxidation. (5 marks)*

d) *Oxidation can occur without the need for elemental oxygen, for example magnesium will react with chlorine in an oxidation reaction to form magnesium ions and chlorine ions. Write a balanced equation that describes this process and use it to give an alternative explanation for oxidation. (4 marks)*

Examiner Feedback

This question required a detailed understanding of the chemistry behind the principle of spontaneous heating. Candidates who displayed a detailed understanding of the chemistry of oxidation and the diverse ways this can be achieved in combustion attained good marks; candidates with knowledge restricted to knowing that an exothermic reaction took place generally scored poorly.

Candidates should have explained oxidation caused by the gaining of oxygen molecules, the loss of hydrogen molecules or the transfer of electrons. Candidates should be able to demonstrate an understanding of chemical equations relating to combustion processes.

Question 5

a) *Acetylene has the chemical formula C_2H_2. Draw its structure and use this to explain its reactivity. (6 marks)*

b) *Explain why acetylene should not be stored where there are copper pipes in the vicinity. (3 marks)*

c) *Like acetylene, benzene has the generic formula C_nH_n. In the case of benzene, n = 6. Draw the structure of benzene and use this to explain the characteristics of burning benzene. (6 marks)*

d) *Benzene burns in oxygen to produce carbon dioxide and water. Use a balanced equation for this reaction to calculate how much oxygen is required for the complete combustion of 1 mol of benzene. (Atomic weights: oxygen = 16, hydrogen = 1, carbon = 12) (5 marks)*

Examiner Feedback

The general understanding of Acetylene demonstrated by many candidates was very poor. Acetylene is a subject of great significance to a firefighter and candidates should therefore be familiar with the chemical composition (triple carbon bond, requiring little energy to initiate a violent reaction) and behaviour.

Candidates should have recognised the structure of the 'benzene ring' and the stable nature of the shared double bonds of the carbon atoms. Once benzene has ignited, it burns with a lazy smokey flame. The high carbon content leads to incomplete combustion.

Question 6

Dalton's Law of Partial Pressures states that the total pressure of a mixture of gases is given by $P_{tot} = P_1 + P_2 + ...P_n$.

A refrigeration sphere of diameter 180cm sits inside an insulated cone-shaped vessel of base diameter 350cm and height 300cm. The vessel contains 10kg of methane at 25^oC. A tube fitted with a one way valve feeds 25kg of oxygen at 12^oC into the vessel and the two gases mix.

a) *Calculate the volume of the vessel. (1 mark)*

b) *Calculate the partial pressures of each gas in the vessel. (11 marks)*

c) *Use Dalton's Law of Partial Pressures to calculate the total pressure of the gas mixture within the vessel. (2 marks)*

d) *If the refrigeration sphere cools the mixture at a rate of 1^oC every 45 seconds, calculate the temperature of the gas mixture after 9 minutes. (6 marks)*

All calculations correct to 2 decimal places

Gas constant = 8.31JK^{-1}mol^{-1}, Atomic weight oxygen = 16, Hydrogen = 1, Carbon = 12

Examiner Feedback

Many candidates were unable to recall the formulas for finding the volume of a cone and a sphere. Such basic mathematical formulas are not provided on the formula sheet.

Candidates should also be familiar with the chemical formulas for simple organic compounds, such as methane, ethane, propane and butane. In this case, many candidates were unable to provide the chemical formula for methane (CH4).

Question 7

a) *Describe electrical resistance. (4 marks)*

b) *Explain four factors (other than potential difference) that affect the electrical resistance of a conductor in a circuit. (12 marks)*

c) *Explain how two of the factors identified in response to part b) can contribute to the initiation of an electrical fire (4 marks)*

Examiner Feedback

An explanation of electrical resistance should have referred to the impeded flow of electrons in a wire rather than physical defects. The factors affecting resistance should have included temperature, cross sectional area, cable length and material type (resistivity).

Question 8

In an AC circuit, a 12 ohm resistor is connected in series with an inductance of 0.15H, across a 100 V_{rms}, 50Hz supply.

a) Calculate the total circuit impedance. (4 marks)

b) Calculate the power factor of the circuit. (2 marks)

c) Calculate the true power dissipated in the circuit. (2 marks)

d) Sketch the impedance phase diagram for this circuit. (3 marks)

e) If a capacitor is to be connected in parallel to reduce the power factor to as near unity as possible, calculate the theoretical value of the capacitor required. Express your answer in microfarads. Comment on the practicality of the value and the consequence of this. (9 marks)

Examiner Feedback

This question covered a subject which is new to the syllabus this year. It was pleasing to see that most candidates had recognised this and studied the circuit theory of AC circuits.

Many candidates selected appropriate formula from the formula sheet and provided accurate calculations for circuit impedance, power factor and power. However, very few candidates were able to provide calculations relating to the addition of a capacitor in the circuit, which changed the circuit from series to parallel. This part of the question required knowledge of the power triangle and reactive power.