IFE Level 4 Certificate in Fire Safety and Fire Science

Unit 1 – Fire Engineering Science

Examiner Report – March 2019

Introduction

Entries for this examination were lower than in previous years with only 78 candidates booking examinations. 26% of candidates who sat the examination were successful in achieving a pass with more than half of the candidates who passed securing a C Grade.

Candidates generally performed best on questions 1, 7 and 8. They performed least well on question 3.

Question 1

a) A horizontal jet of water 20mm in diameter strikes a plate fixed at 20^o to the vertical at a velocity of 10m/s. Calculate the force on the plate. Take the density of water to be $1000kg/m^3$. (5 marks)

b) An industrial process requires sodium hydroxide solution (NaOH) at 20^oC to drive a turbine. The NaOH enters the plantroom via an inlet 2.5m from the ground and through a pipe 120mm in diameter. The pipe runs along a short horizontal section before dropping vertically to run along a further horizontal section 1m from the ground and 100mm in diameter. The turbine is after this second horizontal section and it requires the equivalent energy as 200Pa pressure to operate. A mercury manometer is connected to the pipe immediately after the inlet and immediately before the turbine.

If the flow of NaOH is 2400L/min, use Bernoulli's equation to calculate the pressure difference shown on the manometer in mm of mercury. Take the density of NaOH at 20^oC to be 1.5kg/L, the density of Mercury (Hg) to be 13.6kg/L and acceleration due to gravity to be 9.81m/s/s. Answer to two decimal places. (15 marks)

Examiner Feedback

Part a), which required a simple calculation, was answered well by most of the candidates who attempted it. The correct answer was: force on the plate = 10.74N

Part b) involved a straightforward calculation for a pipe containing a fluid that changed height and diameter. The addition of a turbine was designed to give candidates the opportunity to demonstrate that they understood the continuity equation that is the basis for Bernoulli's Theorem. The turbine removes energy from the system and, to simplify the question, this energy loss was given in terms of equivalent pressure loss; it should therefore be added to the right hand side of the equation. Where this action was taken, the remainder of the question was simply following through a standard Bernoulli calculation.

Question 2

a) Explain what is meant by 'laminar flow'. (5 marks)

b) Explain what is meant by 'turbulent flow'. (5 marks)

c) Describe a diffusion flame. (4 marks)

d) Why is a turbulent diffusion flame more efficient than a laminar diffusion flame? (4 marks)

e) Give and describe one example of a turbulent diffusion flame. (2 marks)

Examiner Feedback

This question was the most popular option for candidates but few candidates scored high marks.

Candidates who secured high marks were able to explain how turbulence and diffusion affect flame height and efficiency.

Part d) was often answered poorly with few candidates able to articulate why a turbulent diffusion flame is more efficient than a laminar flame. Candidates should be aware that a turbulent diffusion flame is more efficient and hotter than a laminar diffusion flame because the turbulence causes greater mixing of the flammable gas/vapour and air along the increased surface area caused by the eddies; there is a far greater surface area in turbulent flames than there would be along the straighter lines at the fuel/oxygen interface in a laminar flame and therefore more fuel and gas can mix and make the combustion process more efficient

In response to part e) few good examples of a turbulent diffusion flame were given with candidates usually referring only to Bunsen flames. An alternative example of a turbulent diffusion flame is an industrial burner where gas injected at a high velocity is ignited in air producing a relatively efficient, hot flame

Question 3

a) Define the Lower Flammability Limit of a combustible gas and compare it with the Lower Explosive Limit.(5 marks)

b) The lower flammability of a mixture containing different gases may be found using the following formula:

$$LFL_{(mix)} = \frac{1}{\Sigma\ \left(\frac{concentration\ of\ component\ in\ air}{Component's\ LFL\ concentration}\right)}$$

Engineers require a gas mixture comprising 23% Carbon Monoxide (CO), 42% Ammonia (NH_4) and 35% Ethane (C_2H_6) for use in an industrial process. For safety reasons, the engineers require this mixture to be at a concentration no higher than 90% of its LFL in air.

This is called its 'safety concentration'. Use the formula above to calculate this 'safety concentration' for the gas mixture.

<u>LFL for components in air:</u>

LFL $_{(CO)}$ = 12.5% , LFL $_{(NH4)}$ = 15%, LFL $_{(C2H6)}$ = 3%

(10 marks)

c) *Explain how you would calculate the concentration of each component in the 'safe concentration' mixture. Calculate this for each component.*

(5 marks)

Examiner Feedback

The first part of this question gave candidates the opportunity to demonstrate understanding of the difference and similarity between Lower Flammability Limit and Lower Explosive Limit; very few stated that the only difference is that an explosion generally requires some kind of suppression to the propagation of a pressure wave.

Candidates who followed the formula provided were able to identify that the engineers require 90% of this = 0.055 and the 'safe concentration' of the mixture in air is 5%.

In response to part c), the concentration of each component in the safe mixture in air could be found by:

- [CO] = 0.23 x 0.055 = 0.0126 or 1.3%
- [NH_4] = 0.42 x 0.055 = 0.023 or 2.3%
- [C_2H_6] = 0.35 x 0.055 = 0.019 or 1.9%

<u>Question 4</u>

a) *Explain the term 'flammability' when referring to liquids. (3 marks)*

b) *Describe two characteristics of a liquid that are required for it to be flammable. (4 marks)*

c) *Use your answer to part b) to explain why ethyl alcohol is flammable but water is not. (5 marks)*

d) *Explain what happens when a spark is introduced to an inverted glass bell jar filled with 100% oxygen gas. (3 marks)*

e) *Compare your answer to part d) with what would happen if the spark were replaced with a lit wooden taper. (3 marks)*

f) *The following is the general equation to describe the complete combustion of a hydrocarbon in air.*

$$C_nH_{2n+2} + \frac{3n+1}{2}O_2 \rightarrow nCO_2 + \frac{2n+2}{2}\ H_2O$$

Use this to write a balanced equation for the complete combustion of Octane in air. (2 marks)

Examiner Feedback

In response to part b), most candidates correctly cited volatility as a characteristic of flammable liquids but few mentioned the requirement for the liquid to undergo oxidation and how that might be achieved.

As a result of failure to consider oxidation in response to part b), candidates often failed to provide a good response to part c). Candidates should be aware that Ethyl alcohol is flammable because it contains carbon in an unsaturated form so it can combine with oxygen to become oxidised and produce carbon dioxide. It is also a liquid at STP that readily gives off a vapour and therefore there is in the required form to sustain combustion. Water however, is already in a highly oxidised state and cannot easily either gain oxygen or lose hydrogen; it therefore does not support combustion

Surprisingly few candidates knew the chemical formula for Octane and therefore many missed the opportunity to secure marks for part f).

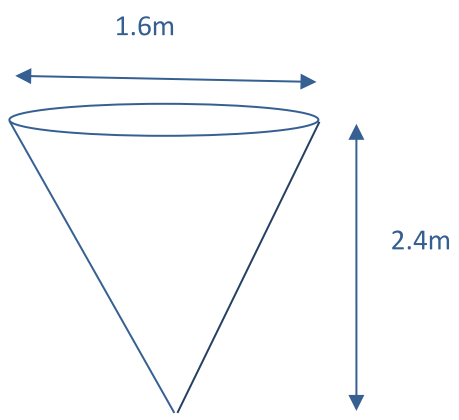
Question 5

a) *Describe Boyle's Law and express it as a formula. (2 marks)*

b) *Describe the ideal gas law and express it as a formula. (2 marks)*

c) *Explain what is meant by the term 'ideal gas'. (3 marks)*

d) *The vessel below is purged with 5.6kg of nitrogen at 21^{O}C after being used to store a volatile substance.*



i) *Calculate the volume of the vessel. (2 marks)*

ii) *Calculate the pressure of the vessel when all of the nitrogen has been introduced. Take the ideal gas constant to be 8.314 and the atomic mass of nitrogen to be 14.*
(4 marks)

Once full, the vessel is heated by a 5kW heater for 3 minutes. If the combined mass of the vessel and contents is 240kg, and the combined specific heat capacity of the vessel and contents is 0.5kJ/kgK:

iii) Calculate the final temperature of the contents. (4 marks)
iv) Calculate the final pressure of the contents. (3 marks)

Examiner Feedback

Candidates often failed to demonstrate understanding of the concept of 'molar mass' and without this they were unable to secure high marks for the calculation.

Similarly, the concept of an 'ideal gas' did not appear to be well understood with many candidates incorrectly believing it to have something to do with compressing gases into liquids by use of pressure. Candidates should be aware that an ideal gas is a theoretical gas composed of many randomly moving point particles whose only interactions are perfectly elastic collisions.

The answers to the calculations were as follows:

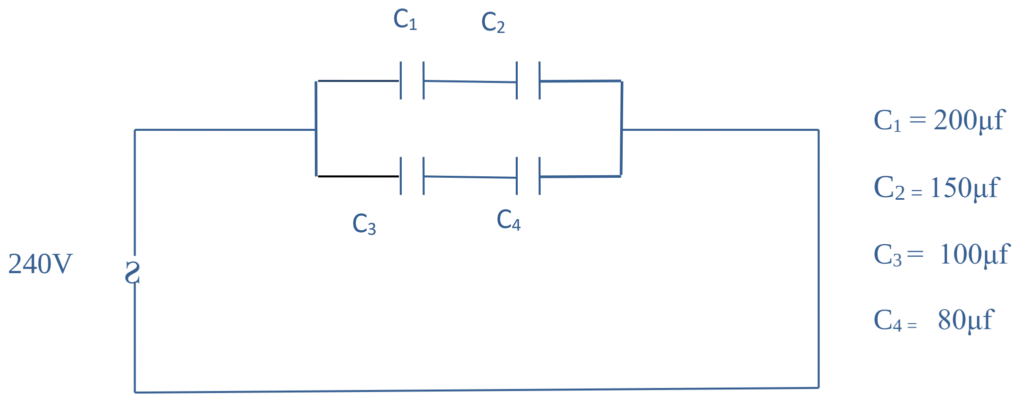
- Volume of vessel = $1.6m^3$
- Pressure of vessel = 305539Pa
- The final temperature will be $28.5^{o}C$
- New pressure will be 313.3kPa

<u>Question 6</u>

a) *Explain the operating principle of a capacitor and explain how it performs its function in a D.C and an A.C circuit. (7 marks)*

b) *Explain how an increase in frequency of an alternating current has the effect of reducing the resistance (reactance) of a capacitor. (2 marks)*

c) *Consider the A.C circuit below:*



i) *If the supply voltage is at 40Hz, calculate the overall capacitance for the circuit. (7 marks)*

ii) *Use your answer to part i) to calculate the current flowing in the circuit. (4 marks)*

Examiner Feedback

This question required the description of a capacitor and then completion of calculations in relation to a simple a.c. circuit diagram involving capacitors in series and in parallel. Few candidates provided correct calculations in response to part c). Correct answers were as follows:

i) Total capacitance = 85.7 + 44.4 = 130.14 μf

ii) $I = \frac{240}{90.47} = 2.65A$

<u>Question 7</u>

a) *Explain the term 'Heat of Combustion' (ΔH_c). (2 marks)*

b) *Explain the relationship between heat of formation (ΔH_f) and heat of combustion (ΔH_c). (2 marks)*

c) *Pentane is a hydrocarbon in the family of alkanes. It contains 5 carbon atoms and each of its chemical bonds are saturated. Explain what is meant by a saturated bond. (3 marks)*

d) *The heat of combustion for pentane is -3509kJ/mol @ 25^oC. What does the negative value -3509 signify? (2 marks)*

e) *Calculate the mass in grams of pentane that must be burned in air to yield 150kJ of heat. (7 marks)* *f) Calculate the mass of oxygen that would be consumed in this reaction. Atomic mass oxygen = 16, hydrogen =1, carbon =12 (4 marks)*

Examiner Feedback

This was the least popular option for candidates.

To secure good marks for this question, candidates required a basic understanding of organic chemistry. The problem involved the simplest family of hydrocarbons, namely alkanes. As with question 5, few candidates were able to utilise their understanding of molar mass to achieve good marks.

Question 8

a)

i) Explain why smoke rises from a fire. (5 marks)

ii) A desktop computer on a desk in a centrally-heated office catches fire and smoke issues from the machine but fails to actuate a smoke detector situated 10m directly above the desk. The automatic fire detection and alarm system are functioning perfectly. Describe what happens to the smoke that prevents the alarm from detecting it. (5 marks)

b) Froude Number is a measure of the relative importance of inertia and buoyancy for a fire's behaviour, particularly flame height. N is a modified version of Froude Number (derived from the heat release rate, Q, and fuel bed diameter, D). It can be shown to correlate well with flame height (l) and the diameter of the fuel bed (D),

i) Using the data given, complete the table. A pre-printed table for completion is provided with this question paper. The completed table should be placed securely inside your answer book. (3 marks)

l	D	N	$\frac{l}{D}$	$Log_{10} \frac{l}{D}$	Log_{10} N
0.395	0.25	1.58×10^{-4}			
1.255	0.5	6.3×10^{-4}			
2.98	0.75	2.5×10^{-3}			
6.3	1.0	0.019			
12.5	1.25	0.158			

ii) Draw a graph using the data calculated in part i) to show the correlation between $Log_{10} \frac{l}{D}$ and Log_{10} N (where $N = Q^2/D^5$) (3 marks) *i) Use your graph to estimate the flame height (l) when the fuel bed diameter (D) is 0.85m and the dimensionless heat release rate (Q) is 0.005.* *(4 marks)*

Examiner Feedback

The question required candidates to offer a scientific explanation of why smoke rises in ambient air. Some candidates provided simplistic statements such as 'smoke rises because it is hot' without reference to molecular movement, energy or density. These statements attracted very few marks.

Part b) required little more than the correct use of a scientific calculator to complete a table of data and then to plot and label a simple graph. This part of the question was popular and generally well answered; however, the final part of the question which required reading data from the graph and performing a reverse of the calculation already completed was not well answered, with very few candidates achieving the correct answer of L = 5 x 0.87 = 4.35m

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