L4C1

THE INSTITUTION OF FIRE ENGINEERS
Founded 1918 • Incorporated 1924

IFE Level 4 Certificate in Fire Science and Fire Safety

Unit 1: Fire Engineering Science (Y/505/5931)

Thursday 14 March 2019

10.30 – 13.30

Instructions to Candidates

1. The time allowed for this examination is **THREE** hours.

2. Candidates must answer **SIX** questions from the total of **EIGHT** questions set for this examination.

3. All questions carry equal marks and may be answered in any order. Candidates should follow the instructions provided in the question when composing their responses.

4. Candidates should record all of their answers in the answer book provided.

5. The question paper must be handed in with the answer book.

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)

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)

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:

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

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>

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

[Please turn over]

Question 4

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)

Question 5

a) Describe Boyle's Law and express it as a formula.

(2 marks)

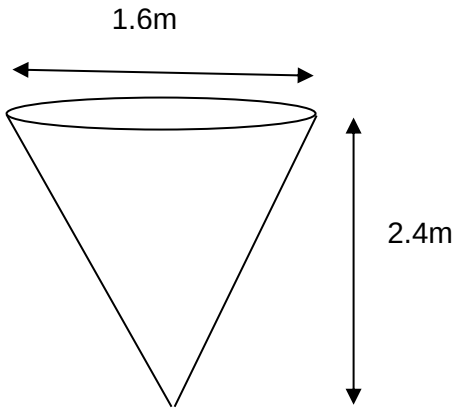
b) Describe the ideal gas law and express it as a formula.

(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)

[Please turn over]

Question 6

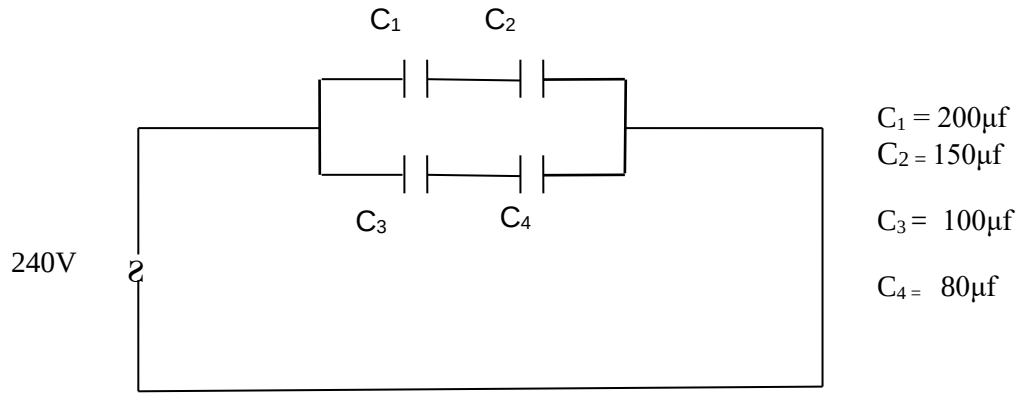
a) Explain the operating principle of a capacitor and explain how it performs its function in a D.C and an A.C circuit.

(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)

Question 7

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^{o}C. 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)

[Please turn over]

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	$1.58x10^{-4}$			
1.255	0.5	$6.3x10^{-4}$			
2.98	0.75	$2.5x10^{-3}$			
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 $N = Q^2/D^5$)

Note: You must use the graph paper provided with this question paper to draw the graph and you should ensure that the graph paper is placed securely inside your answer book.

(3 marks)

iii) 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)