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 12 March 2020

10.30 – 13.30

Instructions to Candidates

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

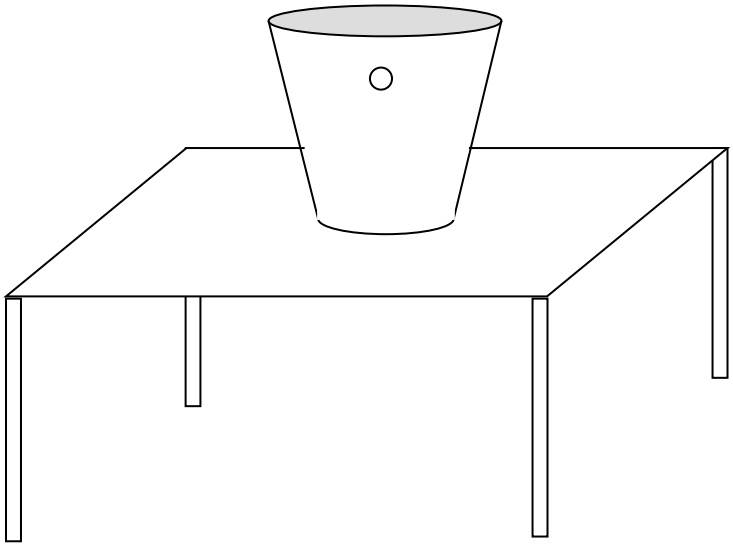
2. Candidates must answer **SIX** questions from the total of **EIGHT** questions set for this examination.

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



Refer to the diagram above. A plastic container, 60cm high and open at the top, is filled with foam concentrate and placed on top of a table which is 1.3m from the floor. The container has a top diameter of 30cm and a bottom diameter of 15cm. A circular hole of 1.5cm diameter is made in the side of the container such that its centre is 20cm from the top. (Density of foam concentrate = 850kgm^{-3})

Complete the calculations below, working in SI units and answering complete to 3 significant figures (s.f).

a) Calculate the mass of foam concentrate in the container.

(5 marks)

b) Use Bernoulli's theorem to calculate the velocity of the foam concentrate as it escapes through the hole.

(8 marks)

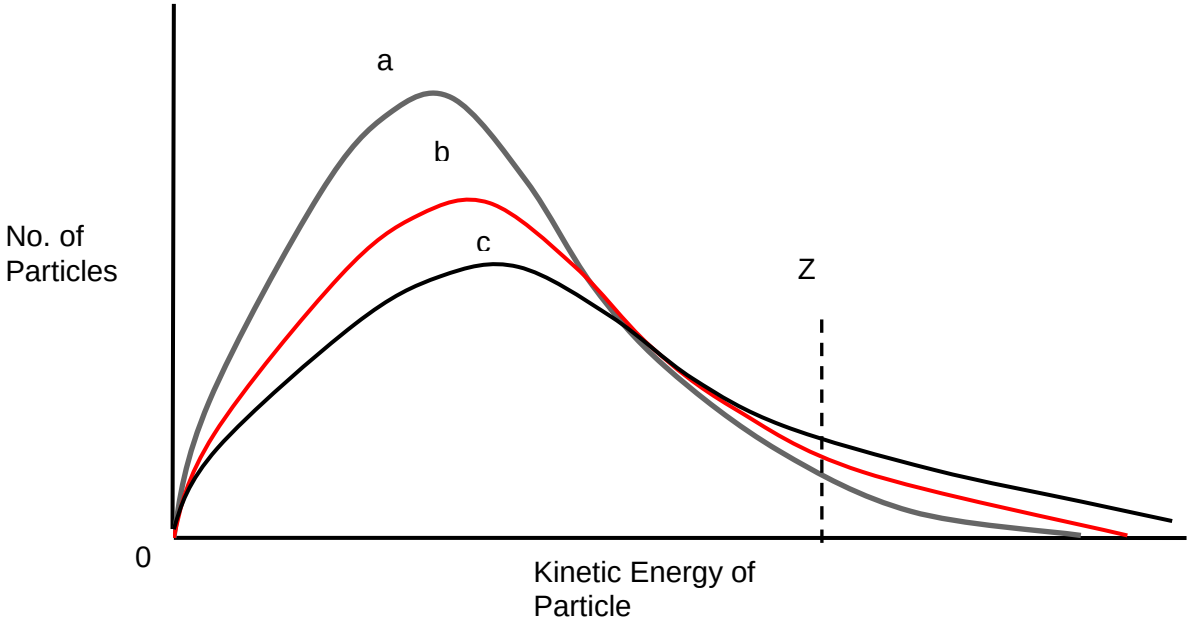
c) Assuming constant flow, calculate how long will it take before the container stops leaking. Ignore any reduction in velocity caused by viscosity.

(7 marks)

Question 2

a) Explain what is meant by “activation energy”. How does it affect the flammability of a substance?

(3 marks)



The graph above is referred to as the Maxwell – Boltzmann Distribution Curve.

b) Describe the curves that are showing.

(5 marks)

c) State the variable that changes between the curves a, b and c on the graph.

(2 marks)

d) Explain why each curve passes through the coordinates 0,0.

(2 marks)

e) State what is indicated by point Z and explain how each curve differs at this point and the significance of that.

(4 marks)

f) Referring to the graph, describe what would be the effect of adding a catalyst to the reaction.

(4 marks)

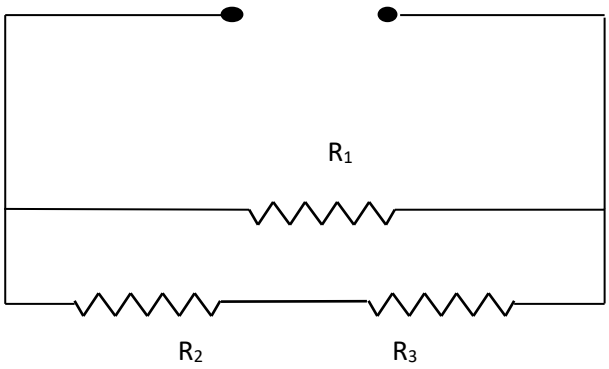
[Please turn over]

Question 3

The photograph below shows an electrical installation that is commonly found in rural areas.

a) Name and briefly describe the parts labelled in the photograph above as A to E.
(5 marks)

b)



Three resistors are placed in an electrical circuit with a $230V_p$ (peak voltage) supply as shown in the figure above. Resistor 1 has an average power rating of 2.5kW, resistor 2 has a resistance of 21.26Ω, and resistor 3 has an average power rating of 4kW. The total peak current flowing in the circuit is 15A. Consider only pure resistance in the circuit, ignoring any reactance.

Calculate the following:

i) the value of the peak current flowing through resistor 3.

(5 marks)

ii) the resistance of resistor 1.

(5 marks)

iii) the resistance of resistor 3.

(3 marks)

iv) the average power rating of resistor 2.

(2 marks)

Question 4

An insulated spherical vessel with a 4m diameter is filled with ammonia gas to a pressure of 2.5 atm. Take the density of ammonia to be 0.73kg/m^3 at 1atm and 20^{o}C and the gas constant to be 8.314, atomic mass nitrogen = 14, hydrogen = 1

a) Calculate the density of the gas inside the vessel once filled.

(2 marks)

b)

i) Use the Gas Laws to calculate the temperature of the gas inside the vessel at equilibrium.

(10 marks)

ii) Describe the assumption you made in your calculation above.

(2 marks)

c) If an internal heating element is used to increase the temperature of the gas by 20^{o}C, calculate the new pressure inside the vessel.

(6 marks)

[Please turn over]

Question 5

a) Explain what is measured in Becquerels.

(2 marks)

b) What is the Sievert and what does it measure?

(2 marks)

c) Explain the connection, and the difference between, the Gray and the Sievert.

(2 marks)

d) Explain the term “effective dose” and state how it is calculated.

(2 marks)

e) State and explain two reasons why it is not a straightforward process to calculate how much radiation is received from an isotope source of known strength.

(4 marks)

f) Thorium 230 has a half life, $t_{1/2,}$ of 8×10^4 years. Sketch a graph using four calculated data points to show how the isotope decays over time.

(8 marks)

Question 6

a) Explain how and why spontaneous smouldering may occur in oil-soaked pipe lagging.

(5 marks)

b) Explain how the autoignition temperature of a hydrocarbon changes with increase in molecular weight.

(2 marks)

c) Explain how spontaneous ignition may occur with rags that have been used to wipe paint brushes or spills.

(5 marks)

d) Compare the situation in part c) with that in part a) and explain the difference.

(5 marks)

e) Some solid fuels, for example coal, are capable of spontaneous ignition. Explain three factors that affect the likelihood of spontaneous combustion occurring in coal.

(3 marks)

Question 7

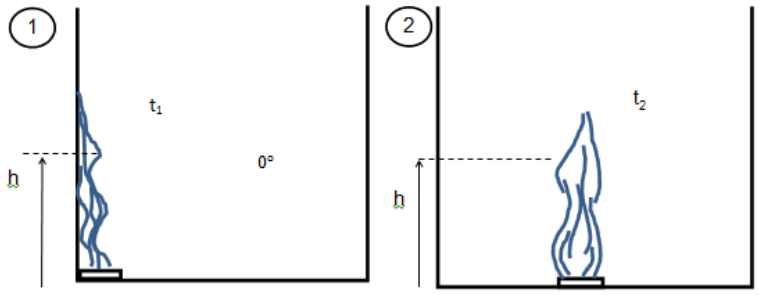
a) Orientation is one factor that affects the rate of spread of flame in solids. Identify and explain five additional factors.

(15 marks)

b) Consider the two situations below. They each show the free burning of identical materials in identical rooms. Situation 1 shows burning against a non-combustible wall; in situation 2, the fire is in the centre of the room. There is no limit to the amount of oxygen available for combustion.

Compare the temperatures t_1 and t_2 of the flame taken at the same height, h, and at the same time in the fire's development in each case. Explain your answer.

(5 marks)



Fire plume against a wall

Fire plume in centre of room

Question 8

a) Using diagrams to support your points, explain the operating principles of a siphon.

(5 marks)

b) Explain how flow is achieved from a system that requires a siphon.

(5 marks)

c) An open V shaped channel has sides inclined at 60° to the vertical. The slope of the channel is 1 in 50 and the depth of flow at the centre is 0.5m. Assuming a Chezy constant of 50 $m^{1/2}/s$, calculate the volume rate of flow.

(10 marks)