NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND SPATIAL SCIENCES

DEPARTMENT OF MECHANICAL, MINING AND PROCESS ENGINEERING

QUALIFICATION: BACHELOR OF ENGINEERING IN METALLURGY	
QUALIFICATION CODE: 08BMET	**LEVEL: 7**
COURSE CODE: PNM 720S	**COURSE NAME: PYROMETALLURGY OF FERROUS METALS**
SESSION: NOVEMBER 2022	**PAPER: THEORY**
DURATION: 3 HOURS	**MARKS: 100**

SECOND OPPORTUNITY QUESTION PAPER	
EXAMINER(S)	**Prof. Sofya Mitropolskaya**
MODERATOR:	**Dr. Silas Ithete Hango (University of Namibia)**

INSTRUCTIONS

1. Answer all the questions.
2. Read all the questions carefully before answering.
3. Marks for each questions are indicated at the end of each question.
4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.

THIS QUESTION PAPER CONSISTS OF 4 PAGES (Excluding this front page)

Question 1 [25 marks]

(a) Figure Q1a features a typical 18th century blast furnace in England. What ways can you suggest to modernize the design in order to improve blast furnace productivity? State and explain five possible interventions. **[5]**

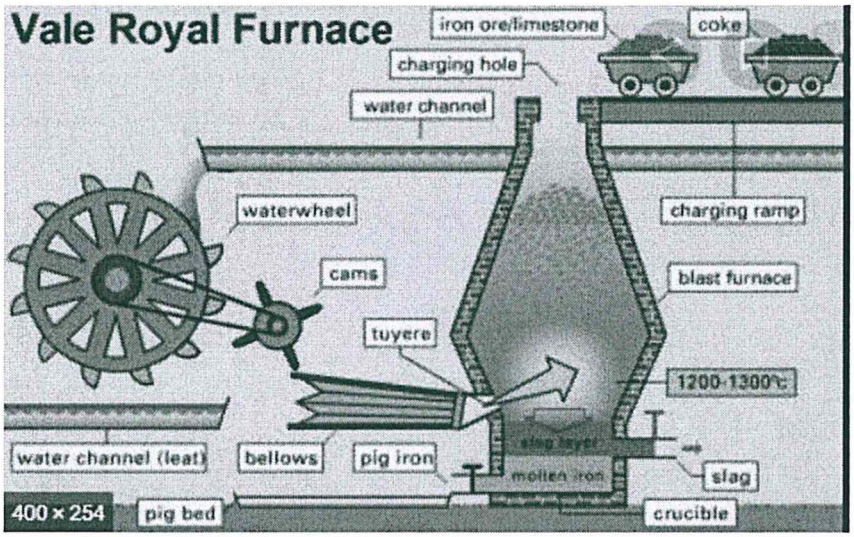

Figure Q1a. Layout of a typical 18th century blast furnace in England.

(b) A blast furnace makes hot metal containing 3.6 wt.% C, 1.1 wt.% Si, 1.3 wt.% Mn, the remainder being Fe. The ore burden contains 80% Fe_2O_3, the remainder being gangue of SiO_2 and Al_2O_3. Calculate the weight of ore W (ore) used for the production of 1 ton of hot metal.

Note: Atomic weights are: Fe = 56, O = 16, C = 12, Si = 28 and Mn = 55. **[15]**

(c) A junior student prepared the C-O-Fe equilibrium diagram for his presentation on blast furnace ironmaking (see Fig. Q1c). However, he forgot to specify the chemical reactions featured by curves (1), (2), and (3). You have noticed that he forgot a very important line (4) in the bottom of the diagram. Draw the line missing in the diagram and indicate all the relevant reactions (1), (2), (3), and (4). **[5]**

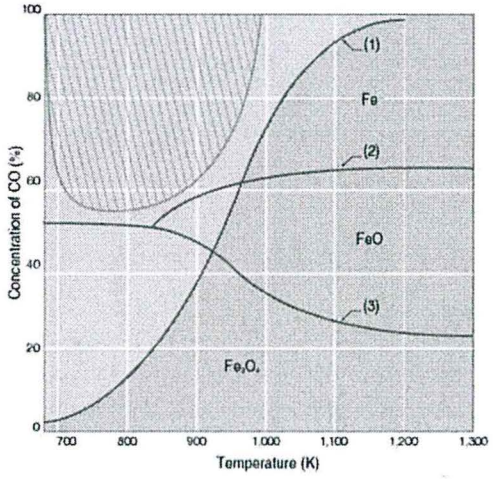

Figure Q1c. The Fe-O-C diagram. One line is missing.

Question 2 [25 marks]

(a) South Africa is a top global manufacturer of ferrochromium. In your opinion, what makes the country a favorable destination for setting up ferroalloy smelters? **[5]**

(b) The World Steel Association recently recommended a number of interventions to mitigate CO_2 emission by the global ironmaking industry. The most ambitious initiative involves the replacement of carbon with green hydrogen. What are the key challenges hindering the implementation of "hydrogen ironmaking"? State and briefly explain five of them. **[5]**

(c) As an expert in ironmaking, you are participating in a public discussion on prospects of an ironmaking plant construction in Namibia. The plant should process local iron ore. Your opponents promote setting up a Blast Furnace plant in Namibia to produce liquid cast iron. In contrast, you argue that the construction of alternative iron making plant will be a better choice for this country. Provide three key technical reasons in favor of the production of sponge iron in Namibia by utilizing gas-based processes of sponge ironmaking. **[15]**

Question 3 [25 marks]

(a) For obtaining the optimum slag viscosity when producing low alloy steel from the low manganese pig iron the composition of Basic Oxygen Converter slag at ArcelorMittal is to meet the following requirements:

$$Al_2O_3 = 5\%;\ SiO_2/CaO = 30/70$$

Indicate and all the necessary tie lines on the diagram provided (Fig. Q3) and estimate the slag composition. **[5]**

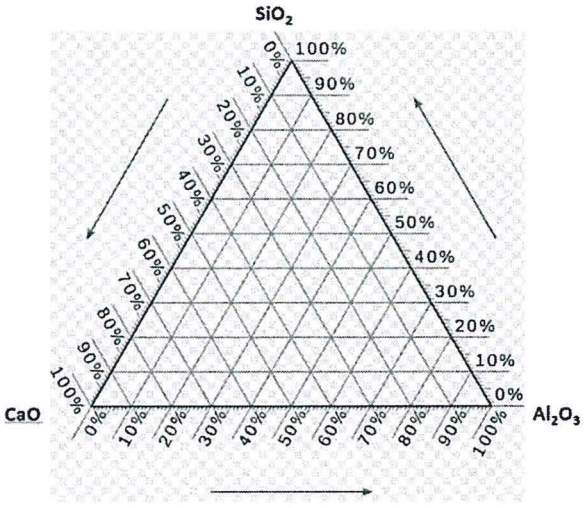

Figure Q3. Ternary diagram for steelmaking slag.

(b) A basic oxygen convertor (BOC) treats the following charge components: 284000 kg hot metal, 4400 kg light scrap; 1000 kg heavy scrap. The post-combustion ratio (PCR) = $\frac{CO_2}{CO+CO_2} = 0.1$ Assume that 11350 kg Fe was oxidized during lancing. The chemical composition of the components is provided in Table Q3.

Table Q3. The chemical composition of charge components.

Charge component	Weight charged (kg)	Chemical composition (wt.%)		
		C	Mn	Fe
Hot metal	284000	4.5	0.5	Balance
Light scrap	4400	0.05	0.12	Balance
Heavy scrap	1000	0.05	0.12	Balance

The target steel chemical composition is given as: 0.16 wt.% C and 1.5 wt.% Mn. The target steel weight is 275 000 kg.

(i) Make up the oxygen balance and calculate the total volume of oxygen used in the BOC process. Note: Atomic weights are – Fe = 56, O = 16, Si = 28, Mn = 55, C = 12. **[15]**

(ii) Estimate the time of blowing in case oxygen is lanced at a constant rate of 3 m^3 per ton per min. **[5]**

Question 4 [25 marks]

(a) Liquid steel is being deoxidized in ladles by the addition of ferrosilicon. The deoxidation product is solid globular silica. In Ladle 1 an average diameter of the silica particles is 5 μm, while in Ladle 2 an average diameter is about 50 μm.

(i) In which ladle a cleaner steel will be produced, if other conditions (the time of treatment, the dimensions of the ladles, etc) are the same? Briefly explain. Assume the rate of settling obeys Stock's law. According to Stokes law, the velocity of elimination of solid globular particles through a layer of molten steel is given by:

$$V = \frac{g d^2 \ (\rho_s - \rho_f)}{18 \ \mu}$$

In this expression V is the velocity of particles elimination from the molten steel (m/s); g is acceleration due to gravity (9.8 m/s^2); d is diameter of the particle (m); ρ_s is the density of silica (2.20×10^3 kg/m^3); ρ_f is the density of liquid steel (7.16×10^3 kg/m^3); and μ is the viscosity of liquid steel, 6.1×10^{-3} kg/(m·s). **[10]**

(ii) Explain the practical steps the Plant Metallurgist should take to increase the velocity of elimination of deoxidation products from the steel and therefore insure faster steel refinement. **[5]**

(b) During the secondary steelmaking processing stirring of a 200 ton ladle of steel is performed by argon injections through porous plug in the bottom. Indicate five technical reasons for stirring the steel bath during secondary steelmaking treatment. [5]

(c) You are casting the following steel using a continuous casting machine:

	C	Si	Mn	P	S
Wt. %	0.1450	0.2000	1.4000	<0.0250	<0.0200

Estimate the required steel temperature before casting. Note that the liquidus temperature as a function of steel chemical composition is given by:

$$T_{liq} = 1537 - 78\%C - 7.6\%Si - 4.9\%Mn - 34.4\%P - 38\%S$$ **[5]**

----------End of Examination----------