University of KwaZulu-Natal

School of Electrical, Electronic and Computer Engineering

Main Examination: November 2025

DURATION: 2 HOURS **TOTAL MARKS: 60**

Examiners: Dr M F Khan
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Mr E Joseph

Your answers to Sections A, B and C must be submitted in SEPARATE examination books.

Section A – Electronic Design: [20 Marks]

A1. A three-way traffic light system requires a timed sequence to control the red, yellow, and green lights. The core of the design utilizes a 555 timer to generate clock pulses and a CD4017 decade counter to control the light sequence.

a. Provide a detailed functional block diagram for this three-way traffic light system. Label all major subsystems. Explain the purpose of each block. [5 marks]

b. The traffic lights need to change sequence every 10 seconds. Using a 555 timer in astable mode, with a timing capacitor of C = 4.7 μF and a resistor R_b = 30 kΩ, calculate the required resistance of R_a to achieve this timing. [5 marks]

A2. A digital logic circuit is to be designed with two inputs (A, B) and one output (Y). The output Y should be high (1) only when the inputs are different from each other.

i. Construct a truth table for this logic function. [2 marks]

ii. Identify the name of the logic gate that performs this function. [1 mark]

iii. Write the corresponding Boolean expression for the output Y. [2 marks]

A3. With respect to digital logic families, define propagation delay and explain why a lower propagation delay is generally desirable in high-speed digital systems [5 marks]

Section B – Instrumentation and Measurement: [20 Marks]

- **Question B1 is comprised of multiple-choice questions worth 2 marks each. Please select the alphabet corresponding to the most correct answer.**
- **For questions B2 to B3, please write complete answers with equations and steps utilized to arrive at the final answer.**

Question B1 [8 marks]

a) The accuracy of a measurement system refers to:
   1. The degree of freedom from random errors.
   2. The closeness of measured value to the true value.
   3. The repeatability of successive readings.
   4. The smallest change that can be detected by the instrument.

b) Which of the following is a systematic error?
   1. Misreading the pointer due to parallax.
   2. Consistent zero shift in a measuring instrument.
   3. Variation due to temperature fluctuations.
   4. Operator fatigue during repeated trials.

c) A PMMC galvanometer can be converted into a voltmeter by:
   1. Connecting a high resistance in parallel with the coil.
   2. Connecting a low resistance in parallel with the coil.
   3. Connecting a high resistance in series with the coil.
   4. Connecting a low resistance in series with the coil.

d) In the Maxwell Bridge shown in Figure 1, at balance:
   1. $L_u = \frac{R_1 R_2}{R_3}$, $R_u = \frac{CR_2}{R_3}$
   2. $L_u = CR_2R_3$, $R_u = \frac{R_2R_3}{R_1}$
   3. $L_u = \frac{R_2}{CR_3}$, $R_u = R_1R_2$
   4. $L_u = \frac{R_2R_3}{C}$, $R_u = \frac{R_3}{R_1}$

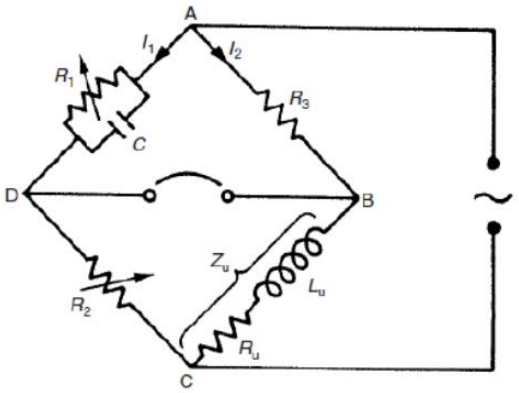


Figure 1: Maxwell Bridge

Question B2 – Loading Effect [6 marks]

A 150 V DC supply is connected across two resistors in series: $R_1 = 50\ k\Omega$ and $R_2 = 100\ k\Omega$. A voltmeter of 200 kΩ internal resistance is used to measure the voltage across R_1.

a) Calculate the true voltage across R_1. **[2]**
b) Calculate the voltmeter reading when connected across R_1. **[2]**
c) Determine the percentage error due to loading effect. **[2]**

Question B3 – Thermocouple Calibration [6 marks]

The following table gives the measured thermocouple output voltage *E* against true temperature *T*.

T (ºC)	100	150	200	250	300
E (mV)	4.1	6.3	8.2	10.5	12.1

a) Using linear regression, determine the best-fit relationship of the form:

$$T = aE + b$$

(You may use least squares formulae without full derivation.) **[4]**
b) Estimate the temperature corresponding to $E = 9.0$ mV **[2]**

Section C – Actuator Design: [20 Marks]

Question C1: Consider the DC electromagnetic actuator shown in Figure C1, which is constructed from Armco Iron (see B_H curves provided). All dimensions shown are in millimeters. The coil of the actuator comprises 300 turns, which is supplied from a DC voltage source.

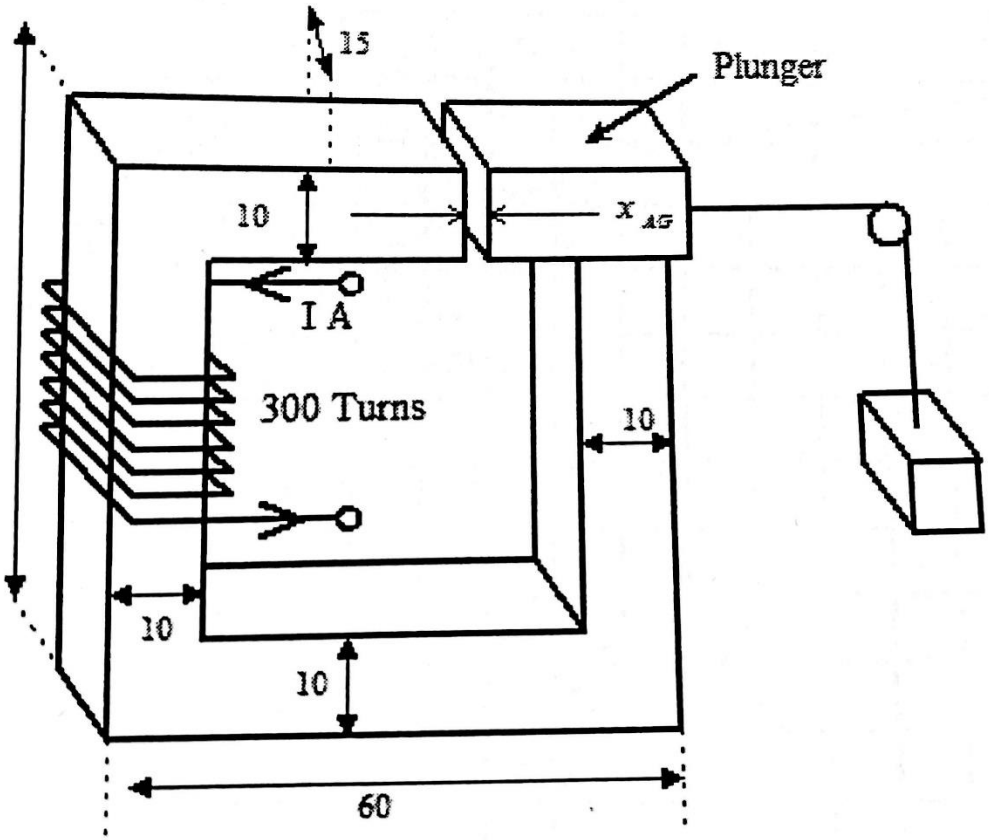


Figure C1

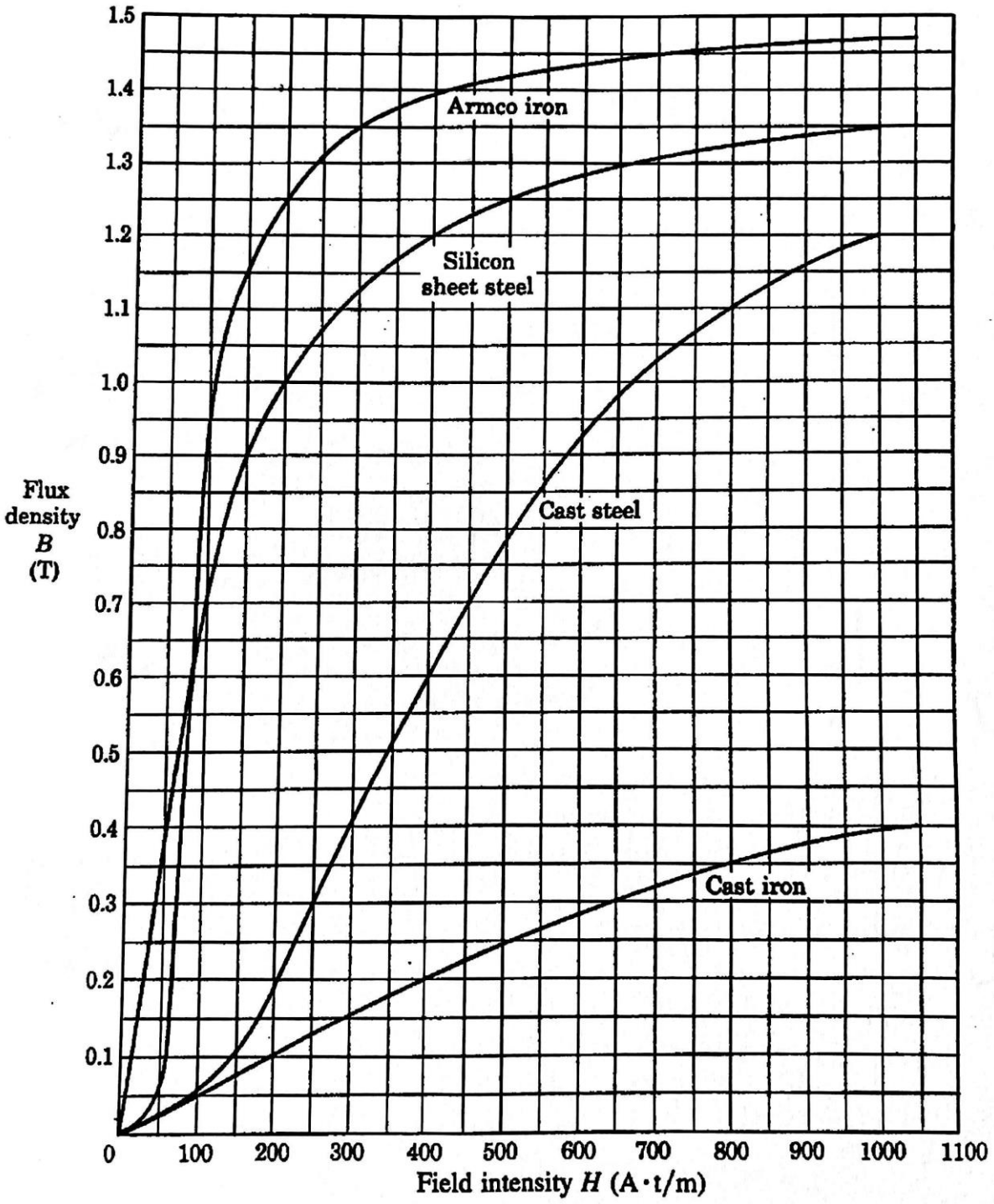
It is desired to operate this actuator at a flux density of 1.35 T when the length of the air gap X_{AG} is 1.0 mm.

1. Calculate the total magnetomotive force (mmf) required at the input to this magnetic circuit (i.e. the required mmf of the coil) in order to achieve the required flux density at an air gap of 1.0 mm. Neglect fringing in the air gap, but **do not neglect the reluctance of the magnetic steel.** [4]

2. From your solution to part (a), calculate the reluctance of the entire magnetic circuit and current I in the coil under these operating conditions [3]

3. Given that when an object is connected to the plunger as shown in Fig. C1, the plunger moves by a horizontal distance of 0.1 mm and thus increases the length of the air-gap to 1.1 mm. Re-calculate the reluctance of the entire magnetic circuit for the condition when the length of the air-gap X_{AG} has been increased to 1.1 mm for the input value of mmf calculated in part (a). Neglect fringing in the air gap but do not neglect the reluctance of the magnetic steel. Work to an accuracy of less or equal to five percent. [8]

4. Estimate the force generated by this actuator for the condition when the length of the air gap X_{AG} is 1.0 mm for the input value of mmf calculated in part (a). Hence, determine the mass of the object in Kg, that the actuator is holding. [g = 9.807 ms^{-2}] [5]


Armco iron
Silicon sheet steel
Cast steel
Cast iron
Flux density B (T)
Field intensity H (A·t/m)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100