ADVANCED LEVEL NATIONAL EXAMINATIONS, 2015,
TECHNICAL AND PROFESSIONAL TRADES

EXAM TITLE: Automation

OPTION: Electricity (ELC)

DURATION: 3 hours

INSTRUCTIONS:
The paper is composed of three (3) Sections:

Section I: Fourteen (14) questions, all Compulsory. 55 marks

Section II: Five (5) questions, Choose Three (3) only. 30 marks

Section III: Three (3) questions, Choose only One (1). 15 marks

Every candidate is requested to strictly obey the above instructions. Punishment measures will be applied to anyone who ignores these instructions.

The use of geometric material and scientific calculator is accepted
Section I. Fourteen (14) Compulsory questions. 55marks

01. What do you mean by:
   a. Hydraulic system?
   b. Sequence valve?
   c. Pneumatics? 6marks

02. State the Boyle's law. 3marks

03. An air compressor takes in air at 105 Pa and 27°C volume of 1.5 m³/kg and compress it to 4.5 x 105 Pa. Find the work done, heat transfer and change in internal energy if the composition is isothermal. 5marks

04. A cylinder is supplied with 100 bar pressure; its effective piston area is equal to 700 mm². Find the maximum force which can be attained. 3marks

05. What is direction control valve? Give its sketch (figure). 4marks

06. How does a limit switch differ from a push button switch? 2marks

07. Find the maximum stroke of a cylinder with rod of 16mm diameter as shown in the figure below: 4marks

08. From the following sketch of switched off 2/3 control valve, design 2/3 control valve in work state. 3marks

09. What is the main difference between a open loop and closed loop system. 10marks
10. Name the components of the following Compressed Air Pneumatic System as represented by the letters bellow:

![Diagram of a pneumatic system with components labeled A, B, C, D, and E.]

5 marks

11. What are the conditions for two cylinders to be synchronized?

3 marks

12. What are the factors to be considered while designing a hydraulic circuit?

3 marks

13. A hydraulic cylinder is used to move a work piece in a manufacturing operation through a distance of 250 mm in 15 s. If a force of 50 KN is required to move the work piece, what is the required working pressure and hydraulic liquid flow rate if a cylinder with a piston diameter of 150 mm is available.

5 marks

14. a) What are the basic elements of PLC?

3 marks

b) What is the difference between PLC and computer?

2 marks

Section II. Answer any three (3) questions of your choice (Do not choose more than three questions). 30 marks

15. a) What are the tasks of a hydraulic reservoir?

b) Indicate the different sections of a hydraulic system.

10 marks

16. Classify the different hydraulic pumps according to the displacement principle.

10 marks
17. An annulus section is formed by placing a stainless steel pipe with an outer diameter of 200mm inside a stainless steel pipe with an inner diameter of 500mm. The annulus section is 10m long and carries water flow rate of 1000 liters/s.

- Relative roughness = 0.00018
- The friction factor = 0.0150.
- Viscosity of the liquid = 1004.10^-9 m²/s.

Determine the nature of the flow and the frictional head loss in meters. 10 marks

18. Draw a circuit diagram of a feed drive using proportional valves. In this circuit we found:

- An electric motor to drive a hydraulic pump which has a fixed displacement and one direction
- A reservoir
- A normal pressure relief valve
- Two pressure gauges: one on pressure line; the other, after the flow control valve and on the port of the DAC (line entering in the large chamber)
- A proportional pressure relief valve
- A proportional directional control valve 4/3 middle center opened
- An adjustable flow control valve to control the flow on the full side of the piston (two ways)

The proportional control valve is actuated by means of an electrical control signal. The control signal influences the flow rate and flow direction. The rate of movement of the drive can be infinitely adjusted by means of changing the flow rate. A second control signal acts on the proportional pressure relief valve. The pressure can be continually adjusted by means of this control signal. 10 marks
19. a) Give at least 5 types of sensors (switches) that are commonly used in electropneumatic and electrohydraulic systems.

b) Draw and name the components of absorption dryer. 10marks

Section III. Answer any one (1) question of your choice (Do not choose more than one question). 15marks

20. The initial values for the volume and pressure of a certain amount of nitrogen gas are \( V_1 = 0.06 \text{ m}^3 \) and \( p_1 = 10^5 \text{ N/m}^2 \), respectively. First, the gas undergoes an isochoric process (process 1-2), which triples the pressure; then it is followed by an isobaric process (process 2-3), which reduces the volume by a factor of three; finally, the volume of the gas is tripled by an isothermal process (process 3-4).

a) Give the initial and final temperatures \( T_1 \) and \( T_4 \) of the gas if the temperature after the first process is \( T_2 = 1083^0 \text{ K} \)

b) Find the volume \( V_4 \) and pressure \( p_4 \) at the final state of the gas

c) How is heat gained by the gas during the first process and how much is heat given away by the gas during the second process? The amount of heat required to raise the temperature of 1 mole of nitrogen by 1^0\text{K} while the gas pressure is kept constant is \( c_p = 29.12/ \text{(mol}^0\text{K)} \).

d) Find the change in internal energy of nitrogen gas by the end of the final process compared to the initial value. 15marks
21. a) A pump has a displacement volume of 200 cm³. It delivers 0.003 m³/s at 1000 rpm and 80 bar. If the prime mover input torque is 350 Nm,
   i. What is the overall efficiency of the pump?
   ii. What is the theoretical torque required to operate the pump?

b) The pump is driven by an electric motor having an overall efficiency of 85%. The hydraulic system operates 10 hours per day for 250 days per year. The cost of electricity is Rwf 150 per kWh. Determine:
   i. The yearly cost of electricity to operate the hydraulic system
   ii. The amount of yearly cost of electricity that is due to inefficiency of electric motor and the pump.

22. a) What is the troubleshooting of a pneumatic service unit?

b) Find the flow rate that an axial piston pump delivers at 1000 rpm. The pump has nine 15-mm diameter pistons arranged on a 125 mm diameter piston circle. The offset angle is set at 10° and the volumetric efficiency is 94%.