

2507/205

MEASUREMENT TECHNOLOGY

Oct./ Nov. 2021

Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN AERONAUTICAL ENGINEERING (AVIONICS OPTION)
MODULE II

MEASUREMENT TECHNOLOGY

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Mathematical tables/ Non programmable scientific calculator;

Drawing instruments.

This paper consists of EIGHT questions.

Answer any FIVE of the EIGHT questions in the answer booklet provided.

All questions carry equal marks.

Maximum marks for each part of a question are as indicated.

Candidates should answer the questions in English.

Take: Electron charge, $e = 1.6 \times 10^{-19} \text{ C}$

Electron mass, $m = 9.1 \times 10^{-31} \text{ kg}$

Acceleration due to gravity = 9.81 m/s^2

This paper consists of 6 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

1. (a) Define each of the following with respect to pressure measurements:
- (i) vacuum pressure;
 - (ii) gauge pressure;
 - (iii) absolute pressure.
- (3 marks)
- (b) Draw a diagram of a U-tube manometer and explain its operation. (6 marks)
- (c) A uniform circular disc has a moment of inertia of 0.2 kg.m^2 and radius of 0.15 m . A force of 20 N is applied tangentially to the disc for 12 seconds . Neglecting frictional losses, determine the:
- (i) torque developed;
 - (ii) angular velocity;
 - (iii) angular acceleration;
 - (iv) kinetic energy of the disc.
- (8 marks)
- (d) Draw a labelled block diagram of pressure measurements system using an elastic element as an input device. (3 marks)
2. (a) (i) State **three** performance characteristics of measuring instruments.
- (ii) Explain each of the following errors with respect to measurement systems:
- (I) operating errors;
 - (II) application errors.
- (7 marks)
- (b) With the aid of a B-H response curve, explain hysteresis with respect to instrumentation systems. (7 marks)
- (c) A voltmeter has a sensitivity of $20 \text{ k}\Omega/\text{V}$ and is set to the 10 V range. It is used to measure the voltage across a circuit having an output impedance of $10 \text{ k}\Omega$ and open circuit voltage of 6 V . Determine the:
- (i) impedance of the voltmeter;
 - (ii) measured voltage;
 - (iii) percentage error in the measured voltage.
- (6 marks)

3. (a) (i) State **three** factors considered when selecting a thermocouple for a particular application.
- (ii) With the aid of a labelled diagram describe the operation of the disappearing-filament pyrometer. (11 marks)
- (b) Draw a labelled diagram of the sight-glass level gauge and describe its operation. (5 marks)
- (c) The pressure on the surface of a liquid in a closed tank is 250 kN/m^2 . A pressure gauge fitted at the bottom side of the tank reads a pressure of 344.2 kN/m^2 . Taking the density of the liquid as 1200 kg/m^3 , determine the:
- (i) height of liquid in the tank;
- (ii) pressure gauge reading after liquid level has fallen by half. (4 marks)
4. (a) (i) State **two** advantages of humistor hygrometers over hair hygrometers.
- (ii) Draw a labelled diagram of a hair hygrometer and describe its operation. (8 marks)
- (b) Figure 1 shows a diagram of an ultrasonic flow meter where l is the distance between the transmitter and receiver. Derive the expression of the transit time (t_1) of sound pulse between transmitter and receiver when the fluid is in motion in terms of transit time with no motion (t_0), velocity of sound (V_s) and velocity of fluid (V). (6 marks)

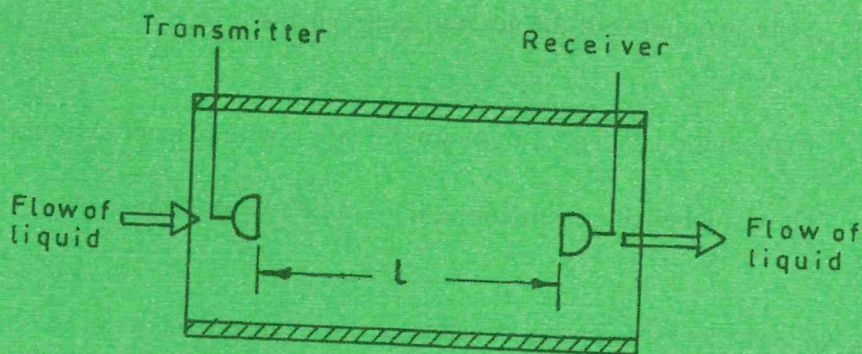


Fig. 1

- (c) Figure 2 shows a diagram of a capillary-type flow meter containing a liquid of density 1150 kg/m^3 . A quantity of 0.216 m^3 flowed in the cylinder in a time of 550 seconds. Determine the:

- (i) discharge rate;
- (ii) dynamic viscosity of the liquid;
- (iii) Reynolds number.

(6 marks)

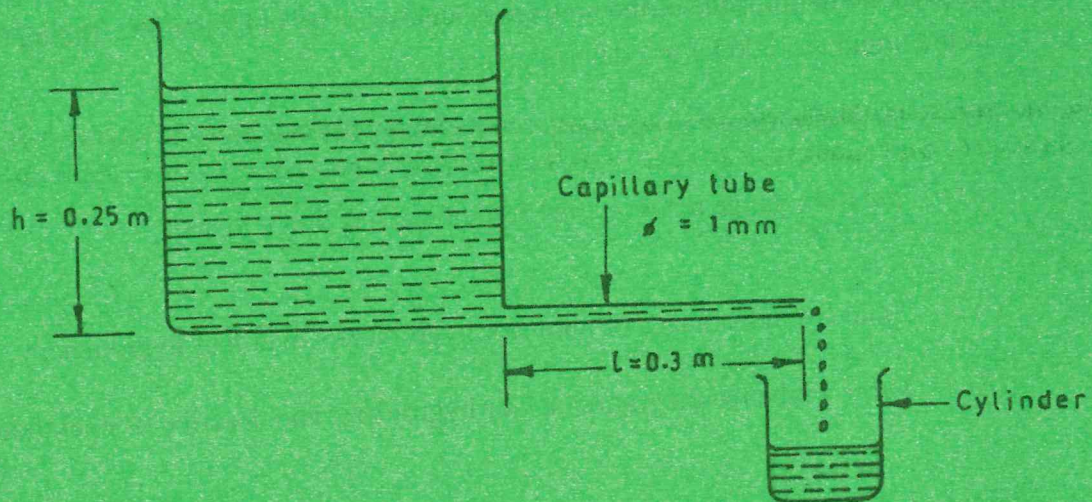


Fig. 2

5. (a) (i) With the aid of a labelled diagram, describe the operation of a Linear Variable Differential Transformer (LVDT) accelerometer.

- (ii) State two merits of the accelerometer in a (i).

(8 marks)

- (b) (i) Explain the concept of light amplification with respect to lasers.

- (ii) Draw a labelled construction diagram of a laser diode.

(8 marks)

- (c) An accelerometer has a spring constant of 240 N/m and a core of mass 0.05 kg . The output of the accelerometer is $14 \text{ mV per } g$, where $g = \text{acceleration due to gravity}$. Determine the:

- (i) sensitivity;
- (ii) natural frequency, in rad/sec.

(4 marks)

6. (a) (i) Draw a labelled diagram of a hydraulic load cell and describe its operation.
(ii) A load cell has a sensitivity of 2 mV/V and an excitation voltage of 5 V d.c. The load capacity of the cell is 500 kg. Determine the:
(I) maximum output voltage;
(II) output voltage at a load of 125 kg. (8 marks)
- (b) With the aid of a labelled diagram, describe the operation of a force-balance pneumatic transmitter. (8 marks)
- (c) A pressure thermometer uses a Bourdon gauge calibrated for a maximum deflection of 300°. A temperature of 180°C gives a deflection of 210°. Determine the:
(i) sensitivity of the thermometer;
(ii) maximum temperature it can indicate. (4 marks)
7. (a) (i) State two properties of ultrasound waves.
(ii) With the aid of a labelled diagram, explain the measurement of fluid velocity using the ultrasonic doppler anemometer. (8 marks)
- (b) A 20 MHz ultrasound wave travels at a velocity of 1340 m/s in tissue 1 and 1150 m/s in tissue 2. Taking the angle of incidence as 40°, acoustic impedance of tissues 1 and 2 as 1.4×10^6 Mray and 8.0×10^6 Mray respectively, determine the:
(i) angle of transmittance;
(ii) reflection coefficient;
(iii) wavelength in tissue 1. (6 marks)
- (c) Draw a labelled diagram of an x-ray spectrometer. (6 marks)

8. (a) (i) State **two** limitations of pitot-static tube when used in flow measurements.
- (ii) Draw a labelled diagram of a rotameter and describe its operation. (8 marks)
- (b) With the aid of a labelled diagram, explain the principle of operation of a flapper-nozzle valve. (6 marks)
- (c) A piezoelectric crystal is 6 mm long, 4 mm wide and 1.5 mm thick. The crystal material has a voltage sensitivity of 0.045 V-m/N and charge sensitivity of 155 pC/N. A force applied to the crystal produces an output voltage of 120 V. Determine the:
- (i) pressure on the crystal;
(ii) magnitude of the force applied;
(iii) charge developed. (6 marks)

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